# UNIT – 2

## TOPICS : FORCE & NEWTON'S LAWS OF MOTION ; DYNAMICS OF CIRCULAR MOTION ; WORK, ENERGY & POWER

## 1. FORCE & NEWTON'S LAWS OF MOTION

■ **Force :** A force can be defined as 'a push or a pull exerted on an object that can cause the object to speed up, slow down, or change direction as it moves or it can change its shape and size'.

● An interaction of one object with another object results in a force between the two objects i.e., to apply force at least two objects are required.

● The effect of a force depends on both magnitude and direction, thus, force is a vector quantity. A force vector points in the direction of the force, and its length is proportional to the magnitude of the force.

● Forces applied on an object in the same direction add to one another. If two forces act in the opposite directions on an object, the net force acting on it is the difference between the two forces.

● **Unit of force :** SI unit - Newton ; c.g.s unit - Dyne **1 N = $10^5$ dynes**

■ **Net force :** If many forces are acting simultaneously on an object, the effect on the object is due to the net force acting on it. The combination of all the forces acting on an object is called net force. The net force acting on an object is also referred as the total force, the resultant force, or the unbalanced force acting on the object.

■ **Contact force :** It is a force that is exerted only when two objects are touching.

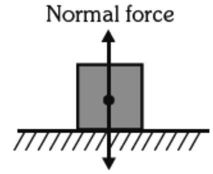
**Examples of contact force**

● **Muscular force :** The force resulting due to the action of muscles is known as the muscular force.

● **Friction :** Friction is a force that resists relative motion. Friction is found everywhere in every material i.e., solids, liquids and gases.

● **Tension :** Tension is a force exerted by string, ropes, fibres, and cables when they are pulled.

● **Normal force :** The force perpendicular to the surfaces of the objects in contact is called normal force.




■ **Noncontact force :** It is a force that one object exerts on another when they are not touching.

**Examples of noncontact force**

● **Magnetic force :** The force exerted by a magnet on a piece of iron or on an another magnet is called magnetic force. Like (or similar) poles repel while unlike (or opposite) poles attract.

● **Electrostatic force :** The force exerted by a charged body on another charged body or uncharged body is known as electrostatic force. Like charges repel and unlike charges attract.

● **Gravitational force :** The attractive force between two objects that have mass is called **gravitational force**. Force of gravity is always attractive in nature and pulls objects toward each other. A gravitational attraction exists between you and every object in the universe that has mass.

■ **Weight :** The force of gravity on an object is called weight.

$$\textbf{Weight} = \mathbf{m \times g}$$

Where, m = mass of object in kg ; g = acceleration due to gravity = 9.8 $m/s^2$ (on surface of Earth)

● Weight is a force, it is measured in unit of force i.e., newtons. At Earth's surface, a 1 kilogram mass has a weight of 9.8 N, a 2 kilogram mass has a weight of 19.6 N, and so on.

■ **Balanced forces :** If the resultant of all forces acting on a body is zero, the forces are called 'balanced forces'.

● If the forces are balanced, this means the acceleration of the object is zero and its velocity remains constant. That is, the object either remains at rest or continues to move with constant velocity.

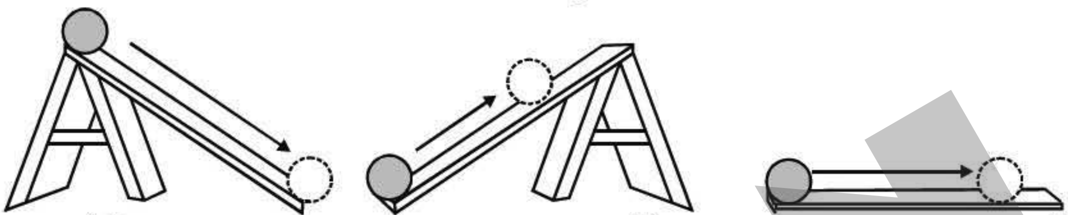
● When forces on an object are balanced, the object is said to be in **equilibrium**. This means, it has zero acceleration which includes, the state of rest as well as, the state of uniform motion.

● **The equilibrium rule:** For any object or system of objects in equilibrium, the vector sum of the forces acting equals zero. In mathematical form, $\sum \vec{F} = 0$ .

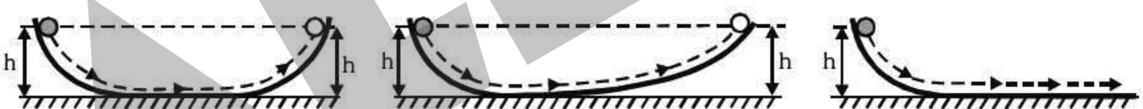
- **Unbalanced forces :** If the resultant of all forces acting on a body is not zero, the forces are called 'unbalanced forces'.
  - In this case, the acceleration of the object is not zero and its velocity changes. That is, unbalanced force changes the state of rest or the state of uniform motion of the object.

- **Galileo's inclined planes**

  Galileo studied motion of objects on an inclined plane. He noted that balls rolling down [see fig.(a)] the inclined planes picked up speed (i.e., acceleration), while balls rolling [see fig.(b)] up the inclined planes lost speed (i.e., retardation). From this he reasoned that balls rolling on [see fig.(c)] a horizontal plane would neither speed up nor slow down. The ball would finally come to rest not because of its 'nature' but because of friction. This idea was supported by Galileo's observation of motion along smoother surfaces. When there was less friction, the motion of objects persisted for a longer time. The smaller the friction, the more the motion approached constant velocity. Galileo concluded that an object moving on a frictionless horizontal plane must neither have acceleration nor retardation, i.e. it should move with constant velocity.




- Another experiment by Galileo leading to the same conclusion involves a double inclined plane. A ball released from rest on one of the planes rolls down and climbs up the other [see fig.(a)]. If the planes are smooth, the final height of the ball is nearly the same as the initial height (a little less but never greater). In the ideal situation, when friction is absent, the final height of the ball is the same as its initial height. If the slope of the second plane is decreased and the experiment repeated, the ball will still reach the same height, but in doing so, it will travel a longer distance [see fig.(b)]. Galileo concluded that 'a ball rolling down the first inclined plane on the left tends to roll up to its initial height on the second plane on the right, thus, the ball must roll a greater distance as the angle of the second inclined plane on the right is reduced'. He argued that when the slope of the second plane is made zero i.e., it becomes a horizontal plane, the ball must travel an infinite distance since it can never reach its initial height on first plane. In other words, its motion never ceases. This is, of course, an idealised situation.




  - Galileo arrived at a new insight that 'the state of rest and the state of uniform motion (motion with constant velocity) are equivalent. In both cases, there is no net force acting on the body. It is incorrect to assume that a net force is needed to keep a body in uniform motion. To maintain a body in uniform motion, we need to apply an external force to encounter the frictional force, so that the two forces sum up to zero net external force. A body does not change its state of rest or uniform motion, unless an external force compels it to change that state. The tendency of things to resist changes in motion was what Galileo called **inertia**.

- **Inertia :** It is 'the natural tendency of an object to remain at rest or in motion at a constant speed along a straight line'. It is the tendency of an object to resist any attempt to change its velocity.
  - The mass of an object is a quantitative measure of inertia. More the mass, more will be the inertia of an object and vice-versa.
  - Inertia of an object can be of three types :

    **Inertia of rest**, the tendency of a object to remain at rest. This means an object at rest remains at rest until a sufficiently large external force is applied on it.

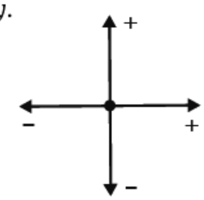
    **Inertia of motion**, the tendency of an object to remain in the state of uniform motion. This means an object in uniform motion continues to move uniformly until an external force is applied on it.

    **Inertia of direction**, the tendency of an object to maintain its direction. This means an object moving in a particular direction continues to move in that until an external force is applied to change it.

- **Newton's first law of motion (Galileo's law of inertia) :** 'Every object continues in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it'.

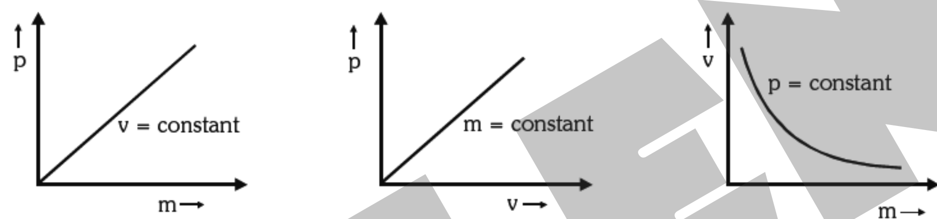
- **Linear momentum (or momentum) :** It is the linear motion contained in an object. Mathematically it is the product of the mass (m) & velocity (v). $\boxed{p = mv}$

  - Linear momentum is a vector quantity. Its direction is 'the direction along the velocity'.
  - The linear momentum of a particle is directly proportional to (i) its mass (ii) its velocity.
  - **Unit of linear momentum :** SI unit : kg m/s or kg m $s^{-1}$ or Newton-second (N-s)
    c.g.s. unit : g cm/s or g cm $s^{-1}$ or Dyne-second
  - Linear momentum can be positive or negative depending on its direction.



Sign convention for momentum

  - For a given velocity, the momentum is directly proportional to the mass of the object ($p \propto m$). This means more the mass, more will be the momentum and vice-versa. If a car and a truck has same velocity, then, the momentum of truck is more than the momentum of car as the mass of a truck is greater than the mass of a car.
  - For a given mass, the momentum is directly proportional to the velocity of the object ($p \propto v$). This means more the velocity, more will be the momentum and vice-versa. If two bodies with same masses move with different velocities then, the body having more velocity will have more momentum.
  - For a given momentum, the velocity is inversely proportional to the mass of the object $(v \propto 1/m)$. This means smaller the mass, more will be the velocity of an object and vice-versa. If a car and a truck has same momentum, the velocity of car will be more than the velocity of truck as the mass of a car is smaller than the mass of a truck.



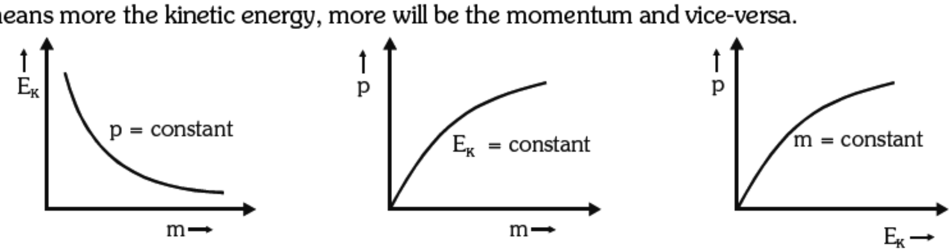

  - When a object is moving along a circular path, its velocity is tangential to the circular path hence, its momentum is also tangential to the circular path.
  - Relationship between momentum and kinetic energy :
    Momentum, p = mv ----- (1)

    Kinetic energy, $E_K = \frac{1}{2}mv^2 = \frac{1}{2}mv^2 \times \frac{m}{m} = \frac{1}{2}\frac{(mv)^2}{m}$ ----- (2)

    From (1) & (2), we get, $\boxed{E_K = \frac{p^2}{2m}}$

    Also, $\boxed{p = \sqrt{2mE_K}}$

  - For a given momentum, kinetic energy is inversely proportional to mass ($E_K \propto 1/m$). This means smaller the mass, more will be the kinetic energy and vice-versa. For a given kinetic energy, momentum is directly proportional to the square root of mass ($p \propto \sqrt{m}$). This means heavier body will have more momentum and vice-versa. For a given mass, momentum is directly proportional to the square root of kinetic energy ($p \propto \sqrt{E_K}$). This means more the kinetic energy, more will be the momentum and vice-versa.




  - **Momentum (p) of a photon :** A photon is considered as massless, chargeless particle of an electromagnetic wave line visible light, X rays, ultraviolet rays, radio waves, etc. but it carries energy.

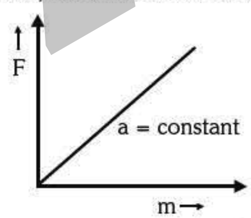
$\boxed{p = \frac{E}{c} = \frac{h\nu}{c} = \frac{h}{\lambda}}$ Where, E = energy carried by a photon = $h\nu$ ; h = Planck's constant = $6.63 \times 10^{-34}$ J s ; $\nu$ = frequency of electromagnetic wave ; $\lambda$ = wavelength of electromagnetic wave.

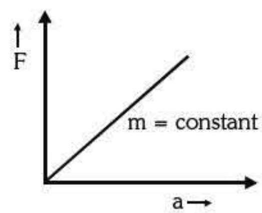
- **Newton's second law of motion :** 'The rate of change of momentum of a body is directly proportional to the applied force and takes place in the direction in which the force acts'. Mathematically, it can be represented as,

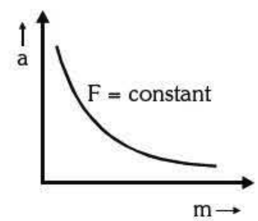
$$\boxed{F = ma = \frac{p_2 - p_1}{t} = \frac{m(v-u)}{t}}$$

- In vector terms, $\vec{F} = m\vec{a}$. If $F_x$, $F_y$, $F_z$ are the components of force in x, y, z direction respectively, the force can be written as, $\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$.
- **Conservative force :** A force is conservative if work done by the force on a particle that moves through any round trip (complete cycle) is zero. e.g. gravitational forces, electrostatic forces, elastic forces are conservative in nature.
- **Non-conservative force :** A force is non-conservative if work done by the force on a particle that moves through any round trip (complete cycle) is not zero. e.g. frictional forces are non-conservative in nature.
- If force is constant i.e., F = ma = constant, then, the acceleration produced in the body is inversely proportional to its mass, i.e, $a \propto 1/m$. This means, if same force F is applied to masses $m_1$ and $m_2$ and the resulting accelerations in them are $a_1$ and $a_2$ respectively, then, $m_1a_1 = m_2a_2$

  or $\boxed{\frac{a_2}{a_1} = \frac{m_1}{m_2}}$.
- When an external non-zero net force acts on an object, the object accelerates in the direction of the net force. The magnitude of the acceleration is directly proportional to the magnitude of the net force and inversely proportional to the mass of the object'. This is an another statement of Newton's second law.
- 1 newton is the amount of force that produces an acceleration of 1 m $s^{-2}$ in an object of 1 kg mass. Similarly, 1 dyne is the amount of force that produces an acceleration of 1 cm $s^{-2}$ in an object of 1 g mass. **1 N = $10^5$ dynes**.
- Force is necessary for changing the direction of momentum, even if its magnitude is constant. We can feel this while rotating a stone in a horizontal circle with uniform speed by means of a string.
- Force, F = Δp/t, this means for a given change in momentum, the force is inversely proportional to the time interval in which this change takes place. Thus, for the same change in momentum brought about in a shorter time needs a greater applied force and vice-versa. For example, an experienced cricketer while catching a cricket ball, allows a longer time for his hands to stop the ball. He moves his hands backward in the act of catching the ball. As the time for catching increases, the force with which the ball hurts his hand decreases. As a result, his hands are not injured.



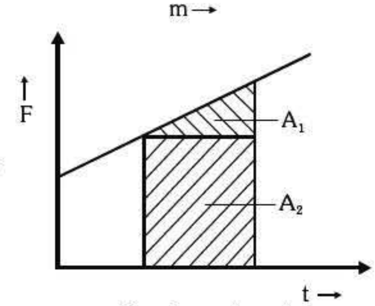




- **Impulse (J) :** The product of force and time is called 'impulse'. It is also the change in momentum of the body. It is a vector quantity.

$$\boxed{J = F \times t = \Delta p = p_2 - p_1 = m\,(v-u)}$$

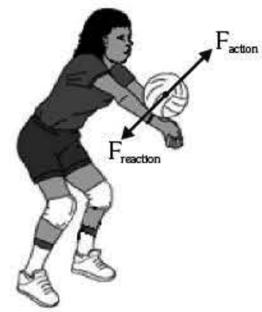
- A large force acting for a short time that produces a significant change in momentum is called an **impulsive force**.

  If force F acting is variable then, impulse, $\boxed{J = F_{av} \times t}$
- Area under the force-time graph gives impulse (see adjoining fig.).

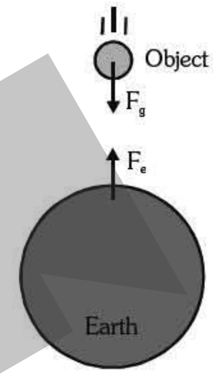



Impulse = $A_1 + A_2$

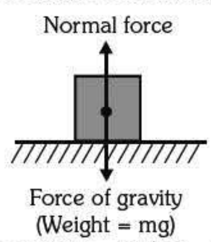
- **Newton's third law of motion :** Whenever one body exerts a force on a second body, the second body exerts an oppositely directed force of equal magnitude on the first body'. '**To every action, there is always an equal and opposite reaction**'.
  - **Forces always exist in pairs :** When two objects interact, two forces will always be involved. One force is the action force and the other is the reaction force.
  - Consider a pair of bodies A and B. According to the Newton's third law, $\mathbf{F_{AB} = -F_{BA}}$
    Where, $F_{AB}$ = force on A due to B and $F_{BA}$= force on B due to A
  - Though action-reaction pair are equal in magnitude and opposite in direction but the reaction force always acts on a different object than the action force. Thus, these forces do not cancel out each other. Hence, there can be an acceleration in an object. For example, a volleyball player while bumping the ball (see figure), the action force is the upward force that the player exerts on the ball. The reaction force is the downward force that the ball exerts on the player's arms. Due to the upward action force, the ball accelerates upward. (The player's arms also accelerate downward but we hardly notice it as mass of the player is quite large).




  - **Newton's third law is applicable to non-contact forces.** For example, the Earth pulls an object downwards due to gravity (see fig.). The object also exert the same force on the Earth but in upward direction. But, we hardly see the effect of the stone on the Earth because the Earth is very massive and the effect of a small force on its motion is negligible. That is, the acceleration of Earth is negligible due to its huge mass.

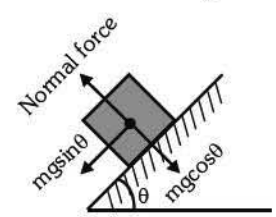



  - Even though the action and reaction forces are always equal in magnitude, these forces may not produce accelerations of equal magnitudes. This is because each force acts on a different object that may have a different masses.
  - **Some important examples of Newton's third law of motion :**
    - When we strike a nail using a hammer to fix in a board, the hammer exerts a downward force on the nail, and the nail exerts an equal and upward force on the hammer.
    - While walking (or running) on a road, we push the road below backwards and the road exerts an equal and opposite reaction force on our feet to make us move forward.
    - When a gun is fired, it exerts a forward force on the bullet. The bullet exerts an equal and opposite reaction force on the gun. This results in the recoil of the gun. Since the gun has a much greater mass than the bullet, the acceleration of the gun is much less than the acceleration of the bullet.
    - When a sailor jumps out of a rowing boat, as the sailor jumps forward, the force on the boat moves it backwards.
    - An inflated balloon recoils when air is expelled from it. When the air is expelled leftward, the balloon accelerates rightward.
    - **Rocket propulsion :** In a rocket engine, the highly combustible fuel burns at a tremendous rate. The rocket exerts a downward (or backward) force on the exhaust gas and thus, the exhaust gas exert an equal upward (or forward) force on the rocket.
    - Like every force, a normal force is one half of an action-reaction pair, so it is often called a '**normal reaction force**'.




Normal force = weight = mg

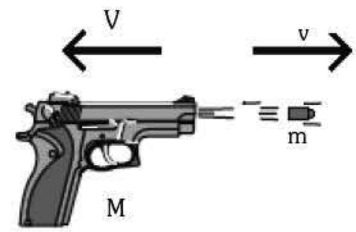
- **Conservation of momentum :** 'When the net external force on a system of objects is zero, the total momentum of the system remains constant'.
  - The total momentum of an isolated system of objects remains constant.
  - The term '**collision**' is used to represent the event of two particles coming together for a short time and thereby producing 'impulsive forces' on each other. These forces are assumed to be much greater than any external forces present because they act for a very short time interval.




Normal force = mgcosθ

- Momentum is conserved for all types of collisions that take place in real world in the absence of any external force.
- Rocket propulsion or the recoil of gun are based on law of conservation of momentum as well as Newton's third law. This is because the law of conservation of momentum is derived using Newton's third law.

Initial momentum = 0




Final momentum = mv – MV = 0

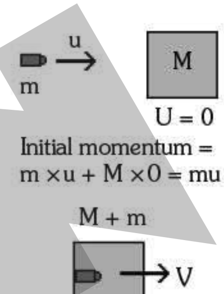
- **Solving problems on conservation of momentum :**
  - **Recoil of a gun :** Initial momentum = Final momentum

    or $0 = MV - mv$ or $\boxed{V = \dfrac{m}{M}v}$ (see fig.)

  - A bullet is fired on a wooden block and it gets embedded in it, after that they move together with a common velocity (see fig.).

    Initial momentum = Final momentum

    or $mu = (M + m)V$ or $\boxed{V = \dfrac{mu}{M+m}}$



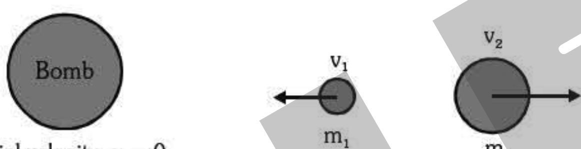

Initial momentum = $m \times u + M \times 0 = mu$

Initial momentum = (M+m)V

  - A bomb of mass M explodes in two parts having masses $m_1$ and $m_2$ (see fig.).

    Final momentum = initial momentum

    or $m_2v_2 - m_1v_1 = 0$ or $\mathbf{m_2v_2 = m_1v_1}$

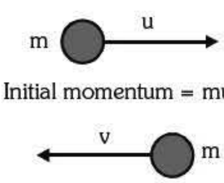



Initial velocity, u = 0
Mass of bomb = M
Initial momentum = $M \times 0 = 0$
(Before explosion)

Final momentum = $m_2v_2 - m_1v_1$
(After explosion)

- **Example :** A batsman hits back a ball straight in the direction of the bowler without changing its initial speed of 12 m $s^{-1}$. If the mass of the ball is 0.15 kg, determine the change in momentum. Also, find the impulse imparted to the ball. (Assume linear motion of the ball).

  **Solution :** See adjoining figure.




Initial momentum = mu

Final momentum = mv

  Initial velocity, $u = +12$ m $s^{-1}$ ;
  final velocity, $v = -12$ m $s^{-1}$ ;
  mass of ball, m = 0.15 kg
  Change in momentum = $mv - mu = m(v - u)$
  $= 0.15 \times [(-12) - (+12)] = -0.15 \times 24$
  $= \mathbf{-3.6\ kg\ m\ s^{-1}}$
  Impulse = change in momentum = $\mathbf{-3.6\ kg\ m\ s^{-1}}$

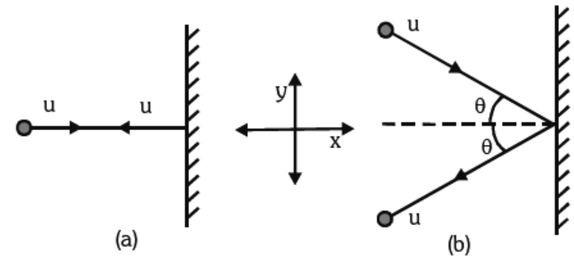
- **Conservation of momentum in three dimensions :** $\sum \overrightarrow{p_x} = 0$ ; $\sum \overrightarrow{p_y} = 0$ ; $\sum \overrightarrow{p_z} = 0$ .
  - **Example :** A bullet of mass 0.04 kg moving with a speed of 90 m $s^{-1}$ enters a heavy wooden block and is stopped after a distance of 60 cm. What is the average resistive force exerted by the block on the bullet ?

    **Solution :** Mass of bullet, m = 0.04 kg ; initial speed, u = 90 $ms^{-1}$ ; final speed. v = 0 ;
    distance, s = 60 cm = (60/100) m = 0.6 m
    From third equation of motion, $v^2 = u^2 + 2as$ or $(0)^2 = (90)^2 + 2a(0.6)$

    or $a = -\dfrac{(90)^2}{2 \times 0.6} = -6750\ ms^{-2}$

    $\therefore$ Force, F = ma = (0.04) (–6750) = **– 270 N**

- **Example :** Two identical billiard balls strike a rigid wall with the same speed but at different angles, and get reflected without any change in speed, as shown in fig. What is (i) the direction of the force on the wall due to each ball ? (ii) the ratio of the magnitudes of impulses imparted to the balls by the wall ?




**Solution :**

Case a : Initial momentum in x direction, $p_{xi} = m(+u) = mu$

Final momentum in x direction, $p_{xf} = m(-u) = -mu$

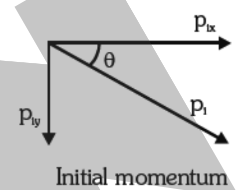
Change in momentum in x direction, $\Delta p_x = p_{xf} - p_{xi} = (-mu) - (mu) = -2mu$

Initial momentum in y direction, $p_{yi} = 0$ ; final momentum in y direction, $p_{yf} = 0$

Change in momentum in x direction, $\Delta p_y = p_{yf} - p_{yi} = 0$

In vector form, we can write, $\overrightarrow{\Delta p} = (-2mu)\hat{i} + 0\hat{j}$

Magnitude of $\overrightarrow{\Delta p}$, $|\overrightarrow{\Delta p}| = \sqrt{\Delta p_x^{\ 2} + \Delta p_y^{\ 2}} = \sqrt{(-2mu)^2 + (0)^2} = \sqrt{4m^2u^2} = 2mu$




Case b : Initial momentum in x direction, $p_{xi} = m(+u\cos\theta) = mu\cos\theta$

Final momentum in x direction, $p_{xf} = m(-u\cos\theta) = -mu\cos\theta$

Change in momentum in x direction,

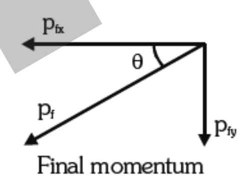
$\Delta p_x = p_{xf} - p_{xi} = (-mu\cos\theta) - (mu\cos\theta) = -2mu\cos\theta$

Initial momentum in y direction, $p_{yi} = -mu\sin\theta$

Final momentum in y direction, $p_{yf} = -mu\sin\theta$

Change in momentum in x direction,

$\Delta p_y = p_{yf} - p_{yi} = (-mu\sin\theta) - (-mu\sin\theta) = 0$




In vector form, we can write, $\overrightarrow{\Delta p} = (-2mu\cos\theta)\hat{i} + 0\hat{j}$

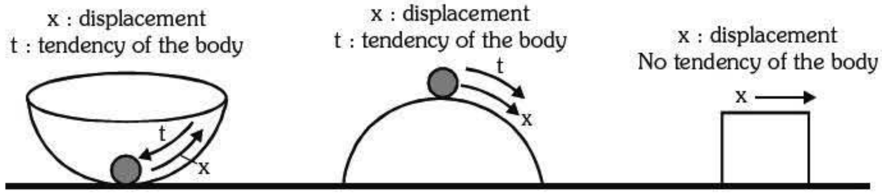
Magnitude of $\overrightarrow{\Delta p}$, $|\overrightarrow{\Delta p}| = \sqrt{\Delta p_x^{\ 2} + \Delta p_y^{\ 2}} = \sqrt{(-2mu\cos\theta)^2 + (0)^2} = \sqrt{4m^2u^2\cos^2\theta} = 2mu\cos\theta$

The ratio of the magnitudes of the impulses imparted to the balls in (a) and (b) is given by,

$(\Delta p)_a/(\Delta p)_b = (2mu)/(2mu\cos\theta) = (1/\cos\theta) = \mathbf{sec\theta}$ ($\because$ Imuplse = change in momentum = $\Delta p$)

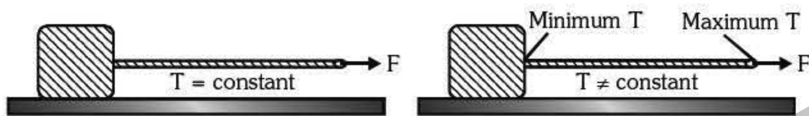
■ **Translatory equilibrium (equilibrium of concurrent forces) :** If many forces are acting on a body simultaneously at the same point, the forces are called **concurrent forces**. If the resultant force due to these concurrent forces is zero, then forces are said to be in equilibrium. That is, $\sum \vec{F} = 0$.

- In three dimensions, $\sum \vec{F_x} = 0$ ; $\sum \vec{F_y} = 0$ ; $\sum \vec{F_z} = 0$.
- If $\sum \vec{F} = 0$, this means, acceleration of the body, $\vec{a} = 0$. This means, velocity, $\vec{v}$ = constant or $\vec{v}$ = 0. In translatory equilibrium, body is either at rest or it is in uniform motion.
- If the body is at rest, the equilibrium is called **static equilibrium**. If body is in uniform motion, the equilibrium is called **dynamic equilibrium**.
- Static equilibrium can be of three types :
  - **Stable equilibrium :** If on slight displacement from the equilibrium position, the body has a tendency to regain its equilibrium position then, the equilibrium is said to be stable equilibrium.
  - **Unstable equilibrium :** If on slight displacement from the equilibrium position, the body has a tendency to move in the direction of the displacement i.e., away from the equilibrium position then, the equilibrium is said to be unstable equilibrium.
  - **Neutral equilibrium :** If on slight displacement from the equilibrium position, the body has no tendency to come back to the equilibrium position or to move away from the equilibrium position, then the equilibrium is said to be neutral equilibrium.



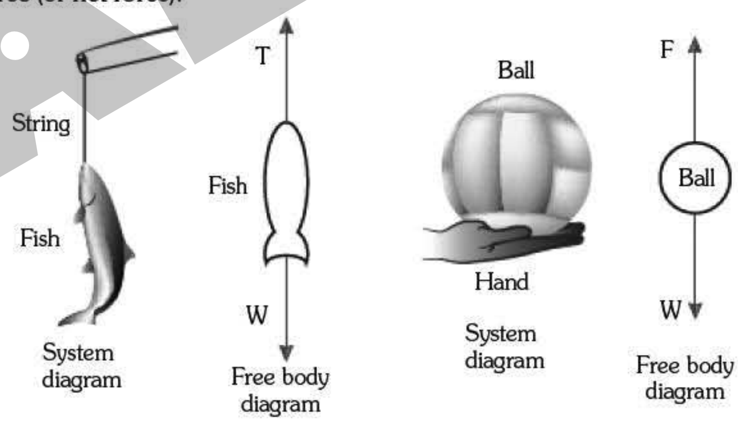

Stable equilibrium Unstable equilibrium Neutral equilibrium

- **Tension in the strings :** Strings are assumed to be inextensible i.e., they cannot be stretched. Due to this assumption 'acceleration of masses connected through a string is always same. They are assumed to be massless unless it is mentioned. Due to this assumption 'tension in the string is same every where'.
  - If the string has mass, tension at different points will be different. It is maximum at the end at which force is applied and minimum at the other end connected to a mass.



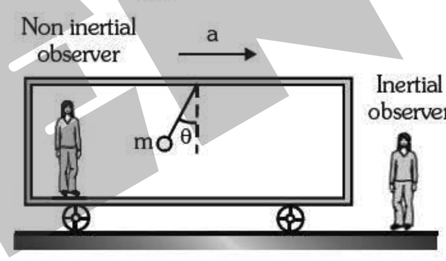

A massless string A string having mass

  - The direction of tension at body (or a point) is always outward along the string i.e., away from the body along the string. Tension always have a pulling action.
- **Free body diagrams :** A system diagram is a sketch of all the objects involved in a situation. A free-body diagram (FBD) is a drawing in which only the object being analyzed is drawn, with arrows showing all the forces acting on the object.
  - Free body diagrams represent all forces acting on one object.
  - Forces that the object exerts on other objects do not appear in free body diagrams because they have no effect on the motion of the object itself.
  - In drawing a free body diagram, you can represent the object as a single dot or a simplified shape the object.
  - In FBD each force acting on the object is represented with an arrow. The arrow's direction shows the direction of the force and the arrow's relative length provides information about the magnitude of the force.
    - Forces that have the same magnitude should be sketched with approximately the same length, forces that are larger should be longer, and smaller forces should be shorter.
  - In case of objects in motion, the direction of acceleration should be made on the FBD in the direction of greater force (or net force).

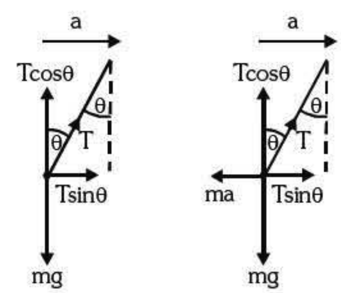



- **Frame of reference :** A frame of reference is a choice of coordinate axes that defines the starting point for measuring any quantity, an essential first step in solving virtually any problem in mechanics.
  - A frame of reference is a coordinate system relative to which a motion can be observed.
  - **Inertial reference frames :** An inertial reference frame is one in which Newton's law of inertia is valid. An inertial reference frame must not be accelerating.
    - An inertial frame of reference is either at rest or moving with uniform velocity.
  - **Non-inertial reference frames :** A non inertial reference frame is one in which Newton's law is not valid. A non inertial reference frame must be accelerating i.e., its velocity is changing with time.

- **Fictitious forces (pseudo forces) :** Anyone who has ridden a merry-go-round as a child has experienced what feels like a "center-fleeing" force. Holding onto the railing and moving toward the center feels like a walk up a steep hill. Actually, this so-called centrifugal force is fictitious. In reality, the rider is exerting a centripetal force on his body with his hand and arm muscles. If the rider's grip slipped, he wouldn't be flung radially away; rather, he would go off on a straight line, tangent to the point in space where he let go of the railing. The rider lands at a point that is further away from the center, but not by "fleeing the center" along a radial line. Instead, he travels perpendicular to a radial line.
  So, we can say a pseudo force is an imaginary force which is experienced by a non inertial observer that is, with respect to a non inertial reference frame.
  - In general, if a particle moves with an acceleration a relative to an observer in an inertial frame, that observer may use Newton's second law and correctly claim that $\sum \vec{F} = m\vec{a}$. If another observer in an accelerated frame tries to apply Newton's second law to the motion of the particle, the person must introduce **fictitious forces** to make Newton's second law work.
  - Fictitious forces 'experienced' by the observer in the accelerating frame appear to be real. But these fictitious forces do not exist when the motion is observed in an inertial frame. Fictitious forces are used only in an accelerating frame and do not represent 'real' forces acting on the particle. By real forces, we mean the interaction of the particle with its environment. Usually, we analyze motions using inertial reference frames, but there are cases in which it is more convenient to use an accelerating frame.
  - To apply Newton's laws in any given problem or situation based on a non inertial reference frame, a fictitious (or pseudo) force is taken just like a part of an action reaction pair and use $\sum \vec{F} = 0$.
  - **Example :** A small sphere of mass m is hung by a cord from the ceiling of a boxcar that is accelerating to the right, as shown in fig. Find the angle θ it makes with the vertical and the tension T in the cord.




**Solution :** Let us solve the problem with respect to an inertial observer (see FBD). According to the inertial observer at rest, $\sum \vec{F} = m\vec{a}$. Here, resolving the components of force in x and y direction, we can write,




FBD for inertial observer

FBD for non inertial observer

x direction : $T\sin\theta = ma$ ----- (1) $[\because a_x = a]$

y direction : $T\cos\theta - mg = 0$ $[\because a_y = 0]$

or $T\cos\theta = mg$ ----- (2)

$\frac{(1)}{(2)} \Rightarrow \frac{T\sin\theta}{T\cos\theta} = \frac{ma}{mg}$ or $\tan\theta = \frac{a}{g}$ or $\boxed{\theta = \tan^{-1}\left(\frac{a}{g}\right)}$

$(1)^2 + (2)^2 \Rightarrow T^2\sin^2\theta + T^2\cos^2\theta = (ma)^2 + (mg)^2$

or $T^2(\sin^2\theta + \cos^2\theta) = m^2(a^2 + g^2)$ $[\sin^2\theta + \cos^2\theta = 1]$

or $\boxed{T = m\sqrt{(a^2 + g^2)}}$

Now, let us solve the problem with respect to a non inertial observer (see FBD). According to the inertial observer at rest,

$\sum \vec{F} = 0$. Here, resolving the components of force in x and y direction, we can write,

x direction : $T\sin\theta - F_{Fictitious} = 0$ $[F_{Fictitious} = ma]$

or $T\sin\theta - ma = 0$ or $T\sin\theta = ma$ ----- (1)

y direction : $T\cos\theta - mg = 0$

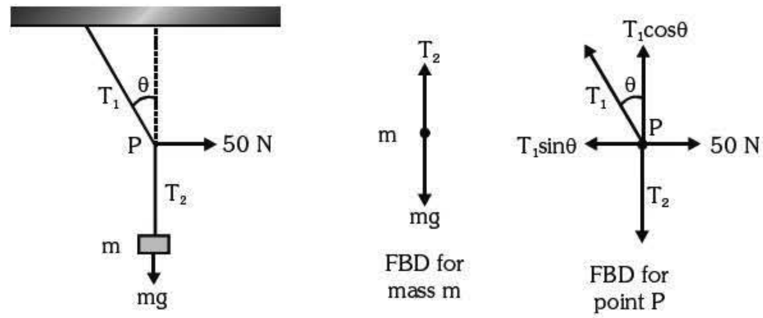
or $T\cos\theta = mg$ ----- (2)

Since, eq.(1) and eq.(2) are exactly same as in the case of an inertial observer, we will get the same result for θ and T.

- **Example :** A mass of 6 kg is suspended by a rope of length 2 m from the ceiling. A force of 50 N in the horizontal direction is applied at the midpoint P of the rope, as shown. What is the angle the rope makes with the vertical in equilibrium ? (Take g = 10 m s$^{-2}$). Neglect the mass of the rope.

  **Solution :** Since the whole system is at rest, net force on the system must be zero i.e., $\sum \vec{F} = 0$ .

  We will make, FBDs for mass m and point P separately (see fig.)




  For mass m, $T_2$ = mg ----- (1)

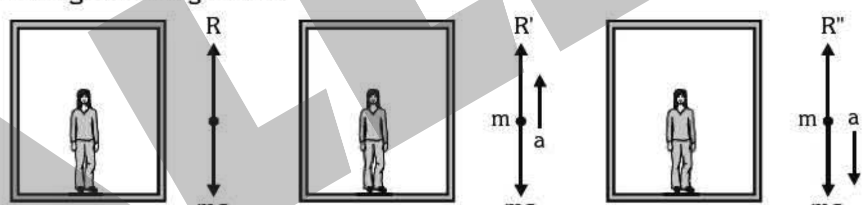
  For point P, $T_1 \sin\theta = 50$ ----- (2) (x direction)

  Also, $T_1 \cos\theta = T_2$ ----- (3) (y direction) Using (1) & (3), we get, $T_1 \cos\theta = mg$ ----- (4)

  $$\frac{(2)}{(4)} \Rightarrow \frac{T_1 \sin\theta}{T_1 \cos\theta} = \frac{50}{mg} \quad \text{or} \quad \tan\theta = \frac{50}{6 \times 10} = \frac{50}{60} \quad \text{or} \quad \tan\theta = \frac{5}{6} \quad \text{or} \quad \boxed{\theta = \tan^{-1}\left(\frac{5}{6}\right)}$$

■ **Weight of an object in a lift :** A weighing machine measures the normal force not the 'true weight'. Thus, if the normal force changes, the weighing machine does not give reading of true weight, it gives a reading of normal force which can be called 'apparent weight' of the object.

- Let us consider a girl standing in a lift.




A lift is at rest or moving with uniform velocity | A lift is moving upwards with uniform acceleration | A lift is moving downwards with uniform acceleration

  ▸ When the lift is at rest or in uniform motion, net acceleration of the system is zero, With respect to an inertial observer, $\sum \vec{F} = m\vec{a}$ (see FBD).

  $\therefore$ mg – R = m × (0) $[\because a = 0]$ or mg – R = 0 or R = mg

  The R represents the apparent weight, i.e., **W = R = mg** [Apparent weight = true weight]

  ▸ When the lift is moving up with uniform acceleration a. Again, with respect to an inertial observer, $\sum \vec{F} = m\vec{a}$ (see FBD).

  $\therefore$ R' – mg = ma [R' is greater force as it is in the direction of acceleration a]

  or R' = ma + mg = m (a + g)

  The R' represents the apparent weight, i.e., **W' = R' = m(a + g)** [Apparent weight > true weight]

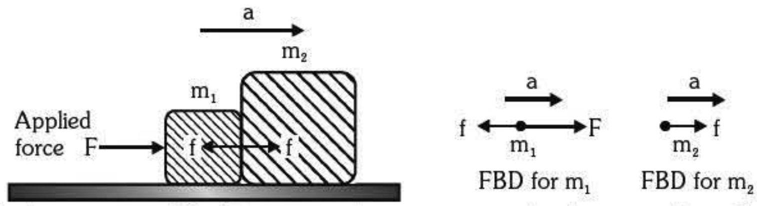
  ▸ When the lift is moving down with uniform acceleration a. Again, with respect to an inertial observer, $\sum \vec{F} = m\vec{a}$ (see FBD).

  $\therefore$ mg – R" = ma [mg is greater force as it is in the direction of acceleration a]

  or R" = mg – ma = m (g – a)

  The R' represents the apparent weight, i.e., **W" = R" = m(g – a)** [Apparent weight < true weight]

- **Motion of bodies in contact :** Let two bodies of masses $m_1$ and $m_2$ respectively are placed side by side touching each other. A push force 'F' is applied on $m_1$ such that both the bodies start moving together with an acceleration 'a'. Since both the bodies are touching each other there is a pair of action reaction force between them at place of their contact. These forces are called normal contact forces (see fig.) and obviously they are equal in magnitude but opposite in direction (Newton's third law).



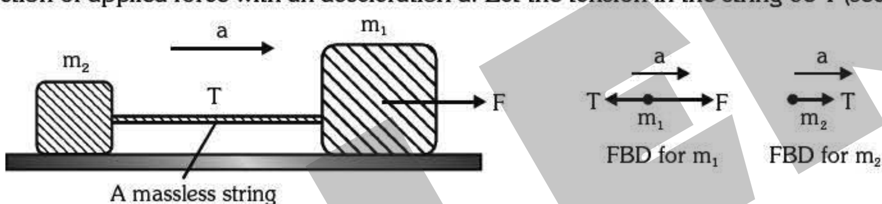

For mass $m_1$, $F - f = m_1 a$ ----- (1) [F is greater force as it is in the direction of acceleration a]

For mass $m_2$, $f = m_2 a$ ----- (2) [Here, f is the only force acting on $m_2$]

(1) + (2) $\Rightarrow$ $(F - f) + f = m_1 a + m_2 a$

or $F = (m_1 + m_2)a$ or $\boxed{a = \frac{F}{m_1 + m_2}}$ From (2), we have, $f = m_2 a$ $\therefore$ $\boxed{f = \frac{m_2 F}{m_1 + m_2}}$

- **Motion of bodies connected by string :** Let us consider two bodies $m_1$ and $m_2$ placed on horizontal frictionless plane connected by a massless string. Let the mass $m_1$ is pulled by a force F. As a result the whole system moves in the direction of applied force with an acceleration a. Let the tension in the string be T (see fig.).



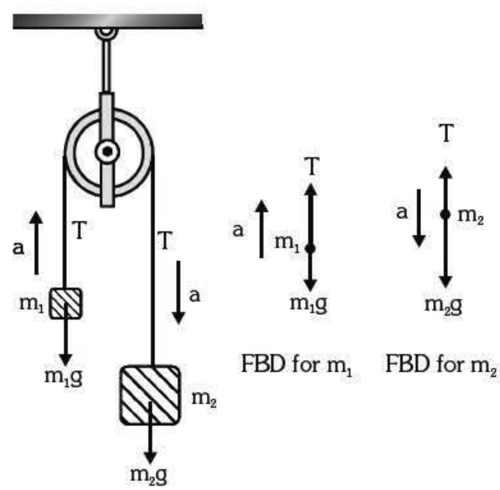

For mass $m_1$, $F - T = m_1 a$ ----- (1) [F is greater force as it is in the direction of acceleration a]

For mass $m_2$, $T = m_2 a$ ----- (2) [Here, T is the only force acting on $m_2$]

(1) + (2) $\Rightarrow$ $(F - T) + T = m_1 a + m_2 a$

or $F = (m_1 + m_2)a$ or $\boxed{a = \frac{F}{m_1 + m_2}}$ From (2), we have, $T = m_2 a$ $\therefore$ $\boxed{T = \frac{m_2 F}{m_1 + m_2}}$

- **Motion of bodies connected by string passing over a light pulley (Atwood's Machine) :** Let us consider two masses $m_1$ and $m_2$ passing over a light pulley connected through a string (see fig.). The term 'light pulley' means the mass of pulley is neglected, it is assumed to be massless. Since the two bodies are connected with each other, both move with same acceleration a. Let $m_2 > m_1$ then, $m_2$ will go downwards while $m_1$ will go upwards.




For $m_1$, $T - m_1 g = m_1 a$ ----- (1)

[Here, $T > m_1 g$, as T is in the direction of acceleration a]

For $m_2$, $m_2 g - T = m_2 a$ ----- (2)

[Here, $m_2 g > T$, as $m_2 g$ is in the direction of acceleration a]

(1) + (2) $\Rightarrow$ $(T - m_1 g) + (m_2 g - T) = m_1 a + m_2 a$

or $(m_2 - m_1)g = (m_2 + m_1)a$

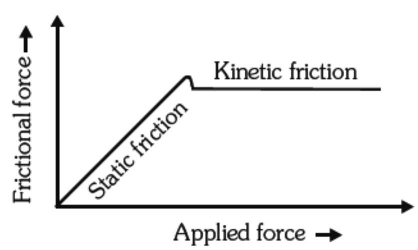
or $\boxed{a = \frac{(m_2 - m_1)g}{(m_2 + m_1)}}$ (Since $a \neq g$, two bodies are not free falling bodies.)

Putting the value of a in eq.(1), we get, $\boxed{T = \frac{2m_1 m_2 g}{m_1 + m_2}}$

- **Friction :** It is a force that opposes the relative movement between two surfaces in contact.
  - The magnitude of the friction force depends on the types of surfaces in contact. The frictional force is usually larger on the rough surfaces and smaller on the smooth surfaces.
  - Friction is always parallel to the surface in contact
  - Friction depends on both of the surfaces in contact, therefore, the value of friction is different for different pairs of surfaces.
  - If an object is allowed to move on a surface then, more the distance travelled by the object on the surface, less will be the friction between them and vice-versa.
  - Friction is caused by the irregularities on the two surfaces in contact.
  - There are many kinds of friction that exist in different media :
    - **Static friction :** It exists when two surfaces try to move across each other but not enough force is applied to cause motion.
    - **Sliding friction :** It exists when two surfaces slide across each other.
    - **Rolling friction :** It exists when one object rolls over another object.
    - **Air friction (air resistance) :** It exists when air moves around an object.
    - **Viscous friction :** It exists when objects move through water or other liquids.
  - Force of friction increases if the two surfaces are pressed harder. The greater the force pressing the two surfaces together, the greater will be the force of friction between them.
  - **Friction increases with weight :** For a heavy object, the weight is quite large, therefore, the force between the object and the floor is also large. Thus, the friction force between them is large.
  - For hard contact surfaces, the force of friction does not depend on the 'area of contact' between the two surfaces. But, it is not true if the surfaces are wet, or if they are soft. Rubber is soft as compared to the surface of a road. The friction between rubber and surface of road also depends on how much rubber is contacting with the surface of road. Thus, wide tires (made of rubber) have more friction than narrow tires.
- **Static friction :** It is the force exerted on an object at rest that prevents the object from sliding.
  - The direction of static friction is opposite to the applied force. Also, it acts in a direction opposite to the direction in which an object tends to move.
  - The maximum value of static friction is called the **starting friction** or **limiting friction**. It is the amount of force that must be overcome to start a stationary object moving.
  - The law of static friction may be written as, $\boxed{f_s \le \mu_s N}$

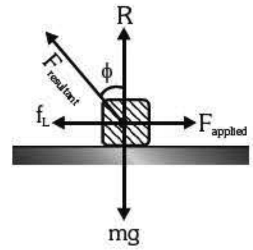
    Where, $\mu_s$ = coefficient of static friction, depends only on the nature of surfaces in contact ;
    N = normal force (or normal reaction).
  - Limiting (maximum) value of static friction is given by, $\mathbf{f_L = \mu_s N}$. If the applied force F exceeds $f_L$ , the body begins to slide on the surface.
  - If applied force F is less than $f_L$, then, $\mathbf{F = f_L}$
- **Sliding friction (or kinetic friction) :** It is the force exerted on an object in motion that opposes the motion of the object as it slides on another object.
  - Sliding or kinetic friction is smaller than the limiting value of static friction. This is because it takes more force to break the interlocking between two surfaces than it does to keep them sliding once they are already moving.
  - Kinetic friction, like static friction, is also found to be independent of the area of contact. Further, it is nearly independent of the velocity of the body.
  - The law of kinetic friction may be written as, $\boxed{f_k = \mu_k N}$

    Where $\mu_k$ is the coefficient of kinetic friction, depends only on the nature of surfaces in contact.
  - $\boxed{\mu_s > \mu_k}$ , $\mu_s$ or $\mu_k$ has not units as they are ratio of two forces.
  - Note that it is not motion, but relative motion that the frictional force opposes.



Variation of friction with applied force

■ **Angle of friction (ϕ)** : The angle of friction (ϕ) is the angle which the resultant of limiting friction $f_L$ and normal reaction R makes with the normal reaction.

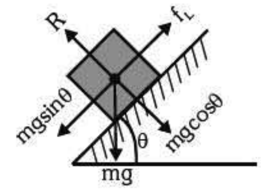



From fig., we have, $\tan\phi = \frac{f_L}{R}$ or $\tan\phi = \frac{\mu_s R}{R}$ or $\boxed{\tan\phi = \mu_s}$

- For smooth surface, ϕ = 0 as there is no friction.

■ **Angle of repose (θ)**

If a body is placed on an inclined plane and if its angle of inclination is gradually increased, then at some angle of inclination θ the body will start just sliding down. This angle of the inclined plane at which the body just starts sliding is called angle of repose (θ).

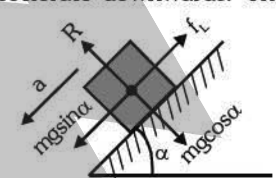



From fig., we have, $f_L$ = mgsinθ ----- (1)

R = mgcosθ ----- (2)

$\frac{(1)}{(2)} \Rightarrow \frac{f_L}{R} = \frac{mg\sin\theta}{mg\cos\theta} = \tan\theta$ or $\boxed{\tan\theta = \mu_s}$

- Thus, **angle of repose = angle of friction on the inclined plane.**
- If angle of inclination (α) of the plane is less than angle of repose (θ), the body will remain at rest. If α = θ, then body will just slide i.e., will move uniformly. If α > θ, the body will accelerate downwards. The acceleration can be found by the given figure :



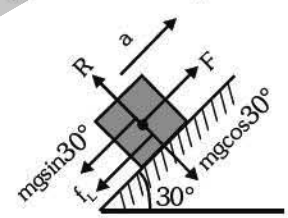

$F_{net} = mg\sin\alpha - f_L = mg\sin\alpha - \mu_s R = mg\sin\alpha - \mu_s mg\cos\alpha$

or $ma = m(g\sin\alpha - \mu_s g\cos\alpha)$

or $\mathbf{a = g(\sin\alpha - \mu_s\cos\alpha)}$

- **Example :** A body of mass 4 kg rests on a rough inclined plane inclined at an angle of 30° with horizontal. But when it is pulled upward by applying a force of 60 N, then an acceleration of 2 m/s² is produced in it. If it is pulled downward by applying a force of 30 N, then what will be the acceleration produced in it ? Take g = 10 m/s².

**Solution :** Case 1 : When the body is pulled upward.



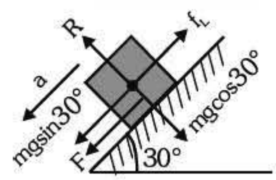

From fig., we have, $F - f_L - mg\sin 30° = ma$

or $60 - f_L - 4g\sin 30° = 4 \times 2$

or $60 - f_L - 4 \times 10 \times (1/2) = 4 \times 2$ or $60 - f_L - 20 = 8$

or $f_L = 32$ N ----- (1)

Case 2 : When the body is pulled downward.




From fig., we have, $F + mg\sin 30° - f_L = ma'$

$30 + 4g\sin 30° - f_L = 4a'$

$30 + 4 \times 10 \times (1/2) - 32 = 4a'$ [Using (1)]

**a' = 4.5 m/s²**

■ **Friction is a necessary evil :** Friction is often undesirable, it causes wear of machine parts, engines, soles of shoes, etc. Thus, friction is an evil. But, it is useful in many cases. For example, walking on the road is not possible without friction. Walking or running on the road involves static friction.

- **Friction is useful for brakes and tyres :** The brakes on a bicycle create friction between two rubber brake pads and the rim of the wheel. Friction between the brake pads and the rim slows down or stops the bicycle. Friction is also necessary to make vehicles go on the road. Without friction the vehicle's tyres would not grip the road.

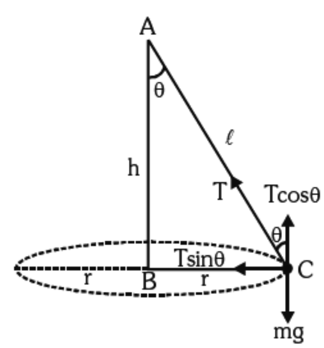
■ **Rolling friction :** The rolling motion of the wheel is a combination of both spin (rotational) motion and linear (translation) motion.

- Rolling reduces the friction significantly.
- When one body rolls over the surface of another body, the resistance (opposition) to its motion is called the **rolling friction**.
- Since the rolling friction is smaller than the sliding friction, sliding is replaced in most machines by rolling by the use of ball bearings.

- **Friction changes energy of motion into heat energy**. Rubbing hands together quickly can make them warmer on a cold day.
- **Fluid friction :** The force of friction exerted by the fluids on the objects moving through them is called fluid friction.
  - The frictional force exerted by fluids is also called **drag**.
  - **Air resistance :** Air resistance is a form of friction that acts to slow down any object moving in the air.
  - **Viscous friction :** The resistance offered by the liquids to the motion of the object moving through them is called viscous friction.
  - **Factors that affect fluid friction :**
    - The speed of the object in the fluid. The faster an objects moves in a fluid, the greater is the fluid friction acting on it.
    - The fluid friction also depends on the shape of the object moving in the fluid. For example, a piece of paper crumpled into a ball falls faster than a flat piece of paper falls. Here, the force of friction on the flat piece of paper is more than the piece of paper crumpled into a ball.
    - Fluid friction also depends on the nature of the fluid. This means a given object experiences different amounts of friction in different fluids. For example, an object moving with a certain speed experiences a greater friction in water than that experienced in air.
- **Reducing friction :**
  - **Lubricants reduce friction in machines :** A fluid used to reduce friction is called a **lubricant**. Oil, water, grease, powdered graphite are used as lubricants. between the moving parts of these machines. In some machines, it may not be advisable to use oil as lubricant.
    - When oil or grease is applied between the moving parts of a machine, a thin layer is formed there and moving surfaces do not directly rub against each other. Interlocking of irregularities is avoided to a great extent. This reduces the friction and the movement of the machine parts becomes smooth.
  - Ball bearings reduce friction.
  - Air cushion reduces friction. For example, a hovercraft floats on a cushion of air created by large fans.
  - Streamlining reduces fluid friction. An object with special curved shape such that the fluid friction on it is minimum is called a streamlined object. Bodies of aeroplanes, cars, etc. are streamlined to reduce fluid friction.
- **Increasing friction :** Grooving the soles of shoes increases friction between the feet and the ground for better grip on the floor, so that we can move safely.
  - Treads on tyres increases friction on pavement (road surface) in dry as well as wet conditions. Treaded tyres of cars, trucks, etc. provide better grip with the ground.

## 2. DYNAMICS OF CIRCULAR MOTION

- **Conical pendulum :** A conical pendulum consists of a bob attached to a string, and it is given a force to revolve in a horizontal circle with uniform speed. Thus, the string makes a cone in the space.




According to the inertial observer at rest, $\sum \vec{F} = m\vec{a}$ . Here, resolving the components of force in x and y direction, we can write (see fig.),

<u>x direction (along the radius)</u> :

$T\sin\theta = ma$ [Here, $T\sin\theta$ is the only force acting along the radius]

or $T\sin\theta = m(v^2/r)$ ----- (1) [a = centripetal force = $v^2/r$]

- Always remember that in a circular motion, there in always a radially inward net force that is responsible for circular motion. In other words, the inwards force is always greater than the outward force (if any) acting on a particle moving along the circular path.

  <u>y direction (vertical direction)</u> : $T\cos\theta = mg$ ---- (2)

$$\frac{(1)}{(2)} \Rightarrow \frac{T\sin\theta}{T\cos\theta} = \frac{m(v^2/r)}{mg} = \frac{v^2}{rg} \quad \text{or} \quad \boxed{\tan\theta = \frac{v^2}{rg}} \text{ ----- (3)}$$

Now, from fig., $\tan\theta = \frac{r}{h}$ and $v = \frac{2\pi r}{t}$ ----- (4) (t = time period of one revoluion)

Using (3) and (4), we get, $\frac{v^2}{rg} = \frac{r}{h}$ or $\frac{(2\pi r/t)^2}{rg} = \frac{r}{h}$

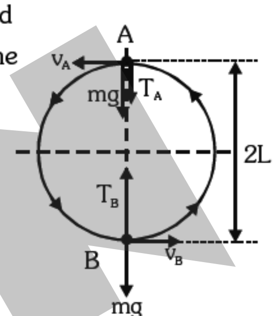
or $\frac{4\pi^2 r^2}{t^2 rg} = \frac{r}{h}$ or $t^2 = \frac{4\pi^2 h}{g}$ or $\boxed{t = 2\pi\sqrt{\frac{h}{g}} = 2\pi\sqrt{\frac{\ell\cos\theta}{g}}}$ $[\because h = \ell\cos\theta]$

$(1)^2 + (2)^2 \Rightarrow T^2\sin^2\theta + T^2\cos^2\theta = (mv^2/r)^2 + (mg)^2$

or $T^2(\sin^2\theta + \cos^2\theta) = m^2[(v^4/r^2) + g^2]$ $[\sin^2\theta + \cos^2\theta = 1]$ or $\boxed{T = m\sqrt{(v^4/r^2) + g^2}}$

■ **Motion in a vertical circle :**

When a body is tied to one end of a string and rotated in a vertical circle, the speed of the body is different at different points of circular path. let m be the mass of the body and L be the length of the string.




- **Velocity at highest point (A) :**

$T_A + mg = ma_A$ or $T_A + mg = m\frac{v_A{}^2}{L}$ or $T_A = m\left(\frac{v_A{}^2}{L} - g\right)$ ----- (1)

If $T_A \geq 0$, the body will complete the circle.

$\therefore$ $m\left(\frac{v_A{}^2}{L} - g\right) \geq 0$ or $v_A{}^2 \geq Lg$ or $v_A \geq \sqrt{Lg}$

Thus, minimum speed required at the topmost point to complete the circle is,

$(v_A)_{min} = \sqrt{Lg}$ .

- **Velocity at highest point (B) :**

$T_B - mg = ma_B$ or $T_B - mg = m\frac{v_B{}^2}{L}$ or $T_B = m\left(\frac{v_B{}^2}{L} - g\right)$ ----- (2)

At lowest point, tension is always greater than zero. Now, applying energy conservation at A and B (assuming potential energy zero at B).

$(K.E)_A + (P.E.)_A = (K.E)_B + (P.E.)_B$

or $\frac{1}{2}mv_A{}^2 + mg(2L) = \frac{1}{2}mv_B{}^2 + 0$ or $\frac{1}{2}m(Lg) + mg(2L) = \frac{1}{2}mv_B{}^2$ (Putting minimum value of $v_A$)

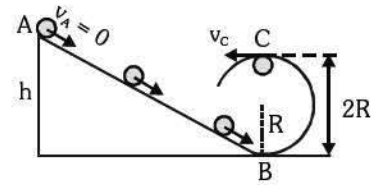
or $\frac{5mgL}{2} = \frac{1}{2}mv_B{}^2$ or $v_B{}^2 = 5Lg$ or $v_B = \sqrt{5Lg}$ (This is the minimum speed at lowest point)

That is, $(v_B)_{min} = \sqrt{5Lg}$ . If $v_B \geq \sqrt{5Lg}$ , the body will complete the circle.

▸ The same formulae of vertical circle are applicable to situations like (i) motion of an aeroplane in a vertical circle (ii) motion of a bucket or tumbler in a vertical circle filled with water, but the water does not fall even the bucket is at the inverted position at the topmost point.

- **Example :** A ball is released from height h as shown in fig. Find the condition for the particle to complete the circular path.

**Solution:** According to law of conservation of energy,




$(K.E)_A + (P.E.)_A = (K.E)_C + (P.E.)_C$

(assuming potential energy zero at B).

or $\quad \frac{1}{2}mv_A^2 + mgh_A = \frac{1}{2}mv_B^2 + mgh_B$

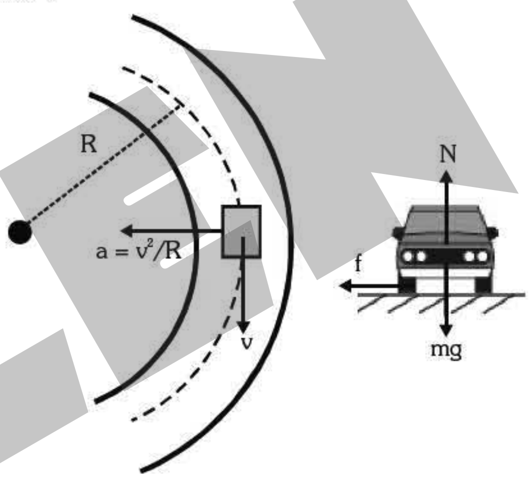
or $\quad \frac{1}{2}m(0)^2 + mgh = \frac{1}{2}m(Rg)^2 + mg(2R)$ (Minimum velocity at topmost point C, $v_C = \sqrt{Rg}$ )

or $\quad mgh = \frac{5mgR}{2}$ or $h = \frac{5R}{2}$

Thus, to complete the circle, $h \geq \frac{5R}{2}$.

## ■ A car taking a turn on a horizontal (level) road :

When a car takes a turn on a level road, the portion of the turn can be assumed to be an arc of a circle of radius R (see fig.) If the car makes the turn at a constant speed v, then there must be some centripetal force acting on the car. This force is generated by the friction between the tyre and the road. This is because car has a tendency to slip radially outward, so frictional force acts inwards.




Let $\mu_s$ is coefficient of static friction;

N = mg be the normal reaction force.

Now, centripetal force = friction provided by tyres

$\therefore \quad \frac{mv^2}{R} = \mu_s N$ or $\frac{mv^2}{R} = \mu_s mg$

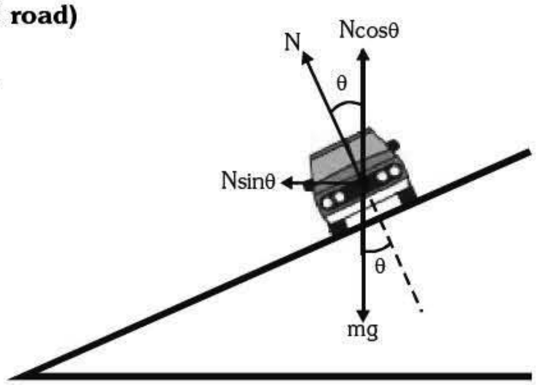
or $\quad v^2 = \mu_s Rg$ or $v = \sqrt{\mu_s Rg}$

This velocity is the maximum safe velocity to take the turn on a horizontal level road.

Thus, for safe turn, $v \leq \sqrt{\mu_s Rg}$.

## ■ Motion of a car on a banked road (banking of road)

While taking a turn, we can not rely totally on friction thus, we raise the outer edge of the circular track slightly above the inner edge. This is called **banking of curved track**. The angle of inclination with the horizontal is called the angle of banking. From fig.,




$N\cos\theta = mg$ ----- (1)

$N\sin\theta = \frac{mv^2}{R}$ ----- (2)

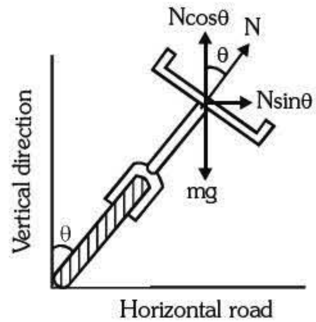
$\frac{(2)}{(1)} \Rightarrow \frac{N\sin\theta}{N\cos\theta} = \frac{m(v^2/R)}{mg} = \frac{v^2}{Rg}$ or $\boxed{\tan\theta = \frac{v^2}{Rg}}$

or $\quad v = \sqrt{rg\tan\theta}$

This is the maximum speed for safe turn. Thus for safe turn, $v \leq \sqrt{rg\tan\theta}$.

- **Bending of a cyclist while making a turn**

Let a cyclist moving on a circular path of radius r bend away from the vertical, towards the center of the circular path by an angle θ. Let N be the normal reaction of the ground. The vertical component of N, Ncosθ balances the weight mg of the cyclist and the horizontal component Nsinθ provides the necessary centripetal force for circular motion. From figure, we have,




$N\cos\theta = mg$ ----- (1)

$N\sin\theta = \dfrac{mv^2}{R}$ ----- (2)

$\dfrac{(2)}{(1)} \Rightarrow \dfrac{N\sin\theta}{N\cos\theta} = \dfrac{m(v^2/R)}{mg} = \dfrac{v^2}{Rg}$ or $\boxed{\tan\theta = \dfrac{v^2}{Rg}}$

or $v = \sqrt{rg\tan\theta}$ This is the maximum speed for safe turn.

Thus for safe turn, $v \le \sqrt{rg\tan\theta}$.

## 3. WORK, ENERGY, POWER

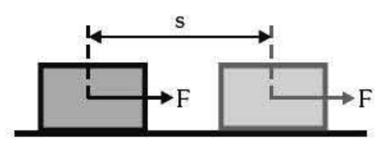
- In common usage, the word 'work' means any physical or mental exertion. But in physics, work has a distinctly different meaning. Let us consider the following situations : (1) A student holds a heavy chair at arm's length for several minutes. (2) A student carries a bucket of water along a horizontal path while walking at constant velocity. (3) A student applying force against a wall. (4) A student studying whole day to prepare for examinations. It might surprise you to know that in all the above situations, no work is done according to the definition of work in physics., even though effort is required in all cases.

- **The concept of work :** In physics, the word 'work' has a definite and precise meaning. Work is not done on an object unless the object is moved with the action of a force. The application of a force alone does not constitute work. For example, when a student holds the chair in his hand, he exerts a force to support the chair. But, work is not done on the chair as the chair does not move.

  - Two important conditions that must be satisfied for work to be done are : (i) a force should act on an object (ii) the object must be displaced. If any one of the above conditions does not exist, work is not done. This is the concept of work that we use in science.

- **Mathematical definition of work :**

  - **A constant force is applied in the direction of the displacement of an object :** Let a constant force, F acts on an object. Let the object be displaced through a distance, s in the direction of the force (see fig.). Let W be the work done. Here, we define work to be equal to '**the product of the force and displacement**'.

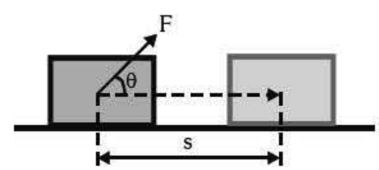



Work done by a constant force cting in the direction of displacement

Work done = force × displacement

$\boxed{W = F \times s}$

  - **A constant force is applied at a certain angle with the direction of the displacement of an object :** When the force on an object and the object's displacement are in different directions, the work done on the object is given by,




Work done by a constant force acting at an angle with the direction of displacement

$\boxed{W = F \times s \times \cos\theta}$

Where, the angle between the force and the direction of the displacement is θ (see fig.).

Here, we define work to be equal to '**the force multiplied by the displacement multiplied by the cosine of the angle between them**'.

  - Work is a scalar quantity, it has only magnitude and no direction.

Work is the scalar product of force and displacement. i.e., $\boxed{W = \vec{F}\cdot\vec{s}}$.

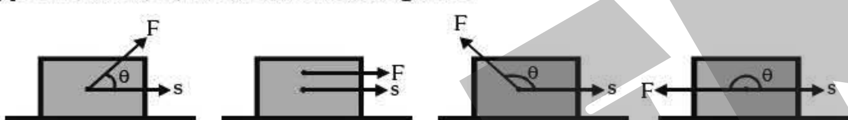
Let $\vec{F} = F_x\hat{i} + F_y\hat{j} + F_z\hat{k}$ and $\vec{s} = x\hat{i} + y\hat{j} + z\hat{k}$. Then, Work done,

$$W = \vec{F}\cdot\vec{s} = (F_x\hat{i} + F_y\hat{j} + F_z\hat{k})\cdot(x\hat{i} + y\hat{j} + z\hat{k}) = xF_x + yF_y + zF_z$$

- **SI unit of work :** Joule   1 Joule = 1 newton ×meter   or   **1 J = 1 N m**
- **Definition of 1 joule :** 1 J is the amount of work done on an object when a force of 1 N displaces it by 1 m along the line of action of the force.
- **Some important points related to work :**
  - If $\theta = 0°$, then $\cos 0° = 1$ and $W = F \times s$.
  - If $\theta = 90°$, then, $W = 0$ because $\cos 90° = 0$. So, no work is done on a bucket being carried by a girl walking horizontally. The upward force exerted by the student to support the bucket is perpendicular to the displacement of the bucket, which results in no work done on the bucket.
  - If $\theta = 180°$, then $\cos 180° = -1$ and $W = -F \times s$.

■ **Concept of negative and positive work :** The work done by a force can be either positive or negative.

- Whenever angle (θ) between the force and the displacement is acute, i.e., $0° < \theta < 90°$, the work done is positive. Also, when angle (θ) between the force and displacement is zero, i.e., force and displacement are in same direction, the work done is positive.
- Whenever angle (θ) between the force and the displacement is obtuse, i.e., $90° < \theta < 180°$, the work done is negative. Also, when angle (θ) between the force and displacement is 180°, i.e., force and displacement are in opposite direction, the work done is negative.




θ is acute angle
Work is positive
(a)

θ is zero
Work is positive
(b)

θ is obtuse angle
Work is negative
(c)

θ is 180°
Work is negative
(d)

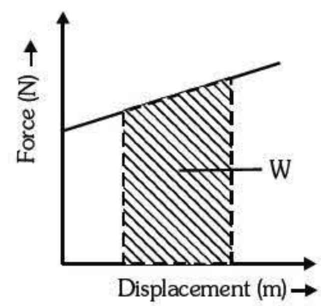
- **Example :** Find the angle between force $\vec{F} = 3\hat{i} + 4\hat{j} - 5\hat{k}$ and displacement $\vec{s} = 5\hat{i} + 4\hat{j} + 3\hat{k}$.

**Solution :** Work done, $W = \vec{F} \cdot \vec{s} = (3\hat{i} + 4\hat{j} - 5\hat{k}) \cdot (5\hat{i} + 4\hat{j} + 3\hat{k}) = (3)(5) + (4)(4) + (-5)(3) = 15 + 16 - 15 = 16$

Now, $\vec{F} \cdot \vec{s} = Fs\cos\theta$

$$\cos\theta = \frac{\vec{F} \cdot \vec{s}}{Fs} = \frac{16}{\sqrt{(3)^2 + (4)^2 + (-5)^2}\sqrt{(5)^2 + (4)^2 + (3)^2}} = \frac{16}{\sqrt{9+16+25}\sqrt{25+16+9}} = \frac{16}{\sqrt{50}\sqrt{50}} = \frac{16}{50} = \frac{8}{25}$$

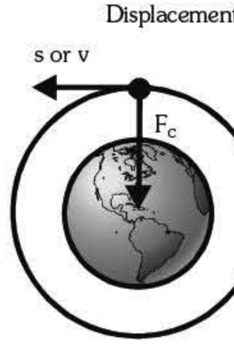
Thus, $\theta = \cos^{-1}\left(\frac{8}{25}\right)$



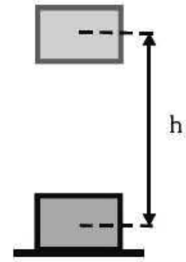

- Area under the force (F) - displacement (s) graph gives the work done on an object or a system.
- An artificial satellite is moving around the Earth in a circular path under the influence of centripetal force provided by the gravitational force between them. Centripetal force (F) is always perpendicular to the displacement (s) of the particle moving along a circular path. That is, the angle (θ) between them is 90°.

  Work done, $W = F\,s\cos\theta = F\,s\cos 90° = 0$

  Thus, work done by this centripetal force is zero.
  - Work done by the centripetal force is always zero because it is always perpendicular to the displacement. For example, if an electron moves around a nucleus in a circular path due to centripetal force provided by the electric force between them, the work done by this force is zero.



- **Work done by applied force against gravity :**

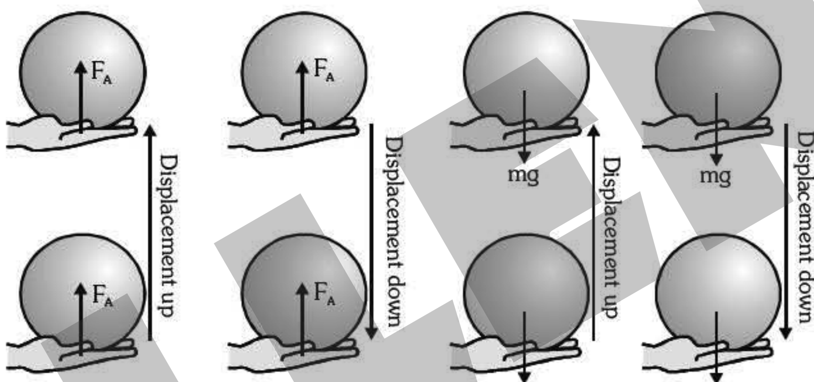



If an object is lifted up to a certain height (see fig), definitely, a work is done by the applied force. The applied force must be equal to the weight (= mg) of the object. This work done is given by,

**W = F × s = mgh**

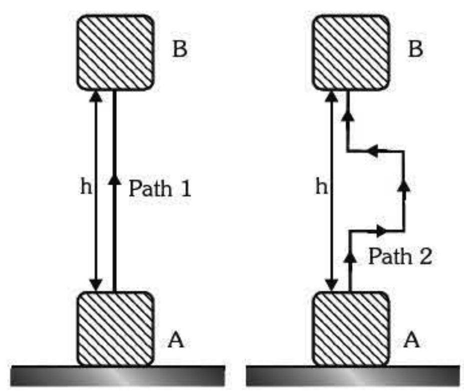
Where, m = mass of object ; g = acceleration due to gravity ; h = height.

- Whenever a person holds an object in his hands or supports an object over his head, he is always applying a force in upward direction.
  - When a person lifts a body from the ground i.e., displaces it in upward direction, the work done by him is positive (see fig.) as force and displacement are in same direction. When a person put an object from a certain height to the ground i.e., displaces it in downward direction, the work done by him is negative (see fig.) as force and displacement are in opposite direction.
  - When a person lifts a body from the ground i.e., displaces it in upward direction, the work done by force of gravity is negative (see fig.) as force of gravity and displacement are in opposite direction. When a person put an object from a certain height to the ground i.e., displaces it in downward direction, the work done by the force of gravity is positive (see fig.) as force of gravity and displacement are in same direction.




Work done by applied force is positive | Work done by applied force is negative | Work done by gravity is negative | Work done by gravity is psoitive

  - The work done against gravity depends on the difference in vertical heights of the initial and final positions of the object and not on the path along which the object is moved. This is because force of gravity is a conservative force. Adjoining figure shows a case where a block is raised from position A to B by taking two different paths. Let the height AB = h. In both the situations the work done on the object is 'mgh'.




- **Energy :** Without light that come to us from the Sun, life on Earth would not exist. With the light energy, plants can grow and the oceans and atmosphere can maintain temperature ranges that support life. Although energy is difficult to define comprehensively, a simple definition is that **energy is the capacity to do work**. Thus, when you think of energy, think of what work is involved.
  - An object that possesses energy can exert a force on another object. When this happens, energy is transferred from first object to the second object. The second object may move as it receives energy and therefore do some work. Thus, the first object had a capacity to do work. This implies that any object that possesses energy can do work.
  - **SI unit of energy :** Since, energy is the capacity to do work, its unit is same as that of work, that is, joule (J). 1 J is the energy required to do 1 joule of work. Sometimes a larger unit of energy called kilo joule (kJ) is used, 1 kJ = 1000 J.

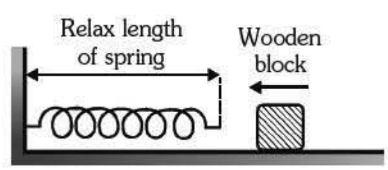
- **Forms of energy :** The world we live in provides energy in many different forms. The various forms include potential energy, kinetic energy, heat energy, chemical energy, electrical energy and light energy.
  - **Mechanical energy :**The capacity to do mechanical work is called mechanical energy. Mechanical energy can be of two types : (1) Kinetic energy (2) Potential energy
  - **Kinetic energy :** This is the energy a body has due to its movement. To give a body KE, work must be done on the body. The amount of work done will be equal to the increase in KE.
    - Kinetic energy is the energy associated with an object in motion.
    - Kinetic energy possessed by an object of mass, m and moving with a uniform velocity, v is

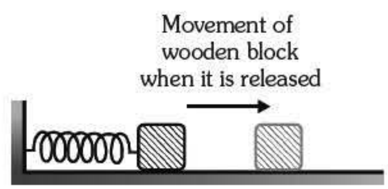
$$\boxed{E_k = \frac{1}{2}mv^2}$$

  - **Potential energy :** The energy possessed by an object due to its position or configuration is called 'potential energy'.
    - Potential energy is associated with an object that has the potential to move because of its position or configuration.
    - **Gravitational potential energy :** The energy associated with an object due to the object's position relative to a gravitational source is called gravitational potential energy.
    - Gravitational potential energy is energy due to an object's position in a gravitational field.
    - Imagine an egg falling off a table. As it falls, it gains kinetic energy. But, where does the egg's kinetic energy come from ? It comes from the gravitational potential energy that is associated with the egg's initial position on the table relative to the floor.
    - We know that, the work done on the object against gravity is W = mgh. This work done is the energy gained by the object. This is the potential energy ($E_p$) of the object. That is,

$$\boxed{E_p = W = mgh}$$

    The above formula actually represents, change in potential energy $\Delta$ PE = $(U_f - U_i)$. Assuming initial potential energy as zero and final potential energy = $E_p$, we get, $\mathbf{E_p = mgh}$.
    - If in a problem, several masses are involved at different vertical positions, then you can assume the potential energy of the mass at the lowest position as zero and you find the potential energies of other masses with respect to the mass at lowest position.
    - **Elastic potential energy** : Suppose a spring is placed on a tabletop and it is fixed at one end. Now, push a block on the spring, compressing the spring, and then release the block. The block slides across the tabletop.




Compressed spring stores elastic potential energy

    - The kinetic energy of the block came from the stored energy in the compressed spring (see fig.). This potential energy is called **elastic potential energy**.
    - Elastic potential energy is stored in any compressed or stretched object, such as a spring or the stretched strings of a tennis racket or guitar.
    - The length of a spring when no external forces are acting on it is called the relaxed length of the spring. When an external force compresses or stretches the spring, elastic potential energy is stored in the spring. The amount of energy depends on the distance the spring is compressed or stretched from its relaxed length.
    - The electric energy stored in a spring is given by,

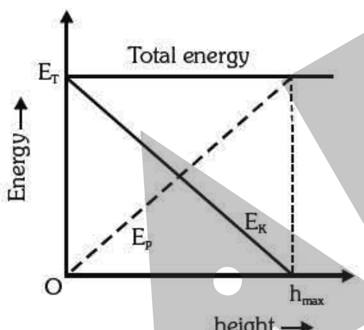
$$\boxed{E_p = \frac{1}{2}Kx^2}$$

    Where, K = spring constant or force constant and x = distance compressed or stretched from the relaxed position of a spring.

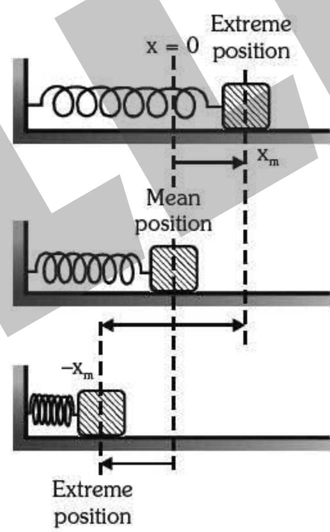
- **Some important points relate to work and energy :**

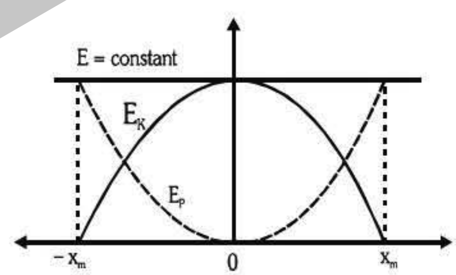
- If several forces are acting on a particle or a system of particles, then the total (or net) work done is given by,
  $W = \vec{F}_{net} \cdot \vec{s}$
  Where, $\vec{F}_{net}$ is the net force (or resultant force) on the particle or system of particles.
- Net work done on a particle or a system of particles is given by,
  $W_{net} = W_c + W_{nc} + W_{ext}$
  - Where, $W_c$ = work done by conservative forces ;
    $W_{nc}$ = work done by the non conservative forces ;
    $W_{ext}$ = work done by external or applied forces.
  - Work done by conservative forces like elastic forces, gravitational forces is given by,
    $W_c$ = – change in potential energy = – $\Delta$ PE = – $(U_f - U_i)$ = $U_i - U_f$
    Where, $U_f$ = final potential energy ; $U_i$ = initial potential energy
  - Work done by non conservative forces like frictional forces, air resistance, etc. is always negative as they are always opposite to displacement.
- Net work done by all the forces i.e., the work done by the unbalanced force is always equal to change in kinetic energy.
  $W_{net} = \Delta\,KE = K_f - K_i$ or $\boxed{W = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2}$
  This is called **work-energy theorem**.
  or $W_c + W_{nc} + W_{ext} = K_f - K_i$
- **Work done by the spring :** Since elastic forces are conservative forces, the work done by the spring is given by,
  $W = -\Delta\,PE = -(U_f - U_i) = U_i - U_f$ or $\boxed{W = \frac{1}{2}Kx_i^2 - \frac{1}{2}Kx_f^2}$
- If non conservative forces are absent, $W_{nc}$ =0. Then,
  $W_c + W_{ext} = K_f - K_i$
  or $U_i - U_f + W_{ext} = K_f - K_i$
  or $\mathbf{W_{ext} = (K_f + U_f) - (K_i + U_i) = E_f - E_i}$
  Where, $E_f$ = final mechanical energy ; $E_i$ = initial mechanical energy
- If non conservative forces are absent, $W_{nc}$ =0 and if no external forces are acting, $W_{ext}$ = 0. Then,
  $W_c = K_f - K_i$
  or $U_i - U_f = K_f - K_i$
  or $U_f + K_f = U_i + K_i$ or $\mathbf{E_f = E_i}$
  Where, $E_f$ = final mechanical energy ; $E_i$ = initial mechanical energy
  Thus, in the absence of non-conservative forces and external forces, total mechanical energy remains conserved or constant.
- If a body is lifted with certain acceleration to reach height h, then work done by the external force is given by,
  $W_c + W_{nc} + W_{ext} = K_f - K_i$
  or $W_c + (0) + W_{ext} = K_f - K_i$ $[W_{nc} = 0]$
  or $(U_i - U_f) + W_{ext} = K_f - K_i$
  or $(0 - U_f) + W_{ext} = K_f - K_i$ [Assuming, $U_i = 0$]
  or $W_{ext} = K_f - K_i + U_f$ or $\boxed{W_{ext} = \left(\frac{1}{2}mv^2 - \frac{1}{2}mu^2\right) + mgh}$

- **The law of conservation of energy :** Energy appears in many forms, such as heat, motion, height, pressure, electricity, and chemical bonds between atoms.
  - **Energy transformations :** Energy can be converted from one form to another form in different systems, machines or devices. Systems change as energy flows from one part of the system to another. Parts of the system may speed up, slow down, get warmer or colder, etc. Each change transfers energy or transforms energy from one form to another. For example, friction transforms energy of motion to energy of heat. A bow and arrow transform potential energy in a stretched bow into energy of motion (i.e., kinetic energy) of an arrow.
  - Energy can never be created or destroyed, just converted from one form into another. This is called **the law of conservation of energy**.
    - The law of conservation of energy is one of the most important laws in physics. It applies to all forms of energy.
  - **Energy has to come from somewhere :** The law of conservation of energy tells us energy cannot be created from nothing. If energy increases somewhere, it must decrease somewhere else. The key to understanding how systems change is to trace the flow of energy. Once we know how energy flows and transforms, we have a good understanding of how a system works. For example, when we use energy to drive a car, that energy comes from chemical energy stored in petrol. As we use the energy, the amount left in the form of petrol decreases.
  - When a body is dropped from a certain height under gravity then, in the absence of any non conservative forces like air resistance, the total mechanical of the body remains constant.
  - When a spring fixed at one end and attached with other end is stretched or compressed on a frictionless surface and then allowed to release, it oscillates about its equilibrium position. But its total mechanical energy remains constant.




$E_K$ = kinetic energy
$E_P$ = potential energy
Energy changes during free fall




$E_K$ = kinetic energy
$E_P$ = potential energy
Energy changes of a vibrating spring

- **Power :** The engine in an old school bus could, over a long period of time, do as much work as jet engines do when a jet takes off. However, the school bus engine could not begin to do work fast enough to make a jet lift off. In this and many other applications, the rate at which work is done is more critical than the amount of work done.
  - Power is the rate at which work is done. Power can also be defined as the rate at which energy is transferred.

$$P = \frac{\text{Work done}}{\text{time taken}} = \frac{W}{t}$$

**SI unit of power :** Watt (W)  1 Watt = 1 joule/second
or **1 W = 1 J s$^{-1}$**
**Definition of 1 watt :** If 1 joule work is done per second by a device or a machine then the power of that device or machine is 1 watt.

node05\B0AI-B0\CBSE\Excellent module\9th\Physics-1\Unit-2\2.IJSO-UNIT-2 (Th).p65

- Power is also expressed in terms of scalar product of force and velocity i.e.,

$$\boxed{P = \vec{F} \cdot \vec{v}}$$

■ **Commercial unit of energy :** The unit joule is an extremely small unit, it is inconvenient to express large quantities of energy in terms of joule. We use a bigger unit of energy called kilowatt hour (kW h). It is called commercial unit of energy.

- **Definition of 1 kWh :** If a machine or a device of power 1 kW or 1000 W is used continuously for one hour, it will consume 1 kW h of energy. Thus, 1 kWh is the energy used in one hour at the rate of 1000 W (or 1 kW).

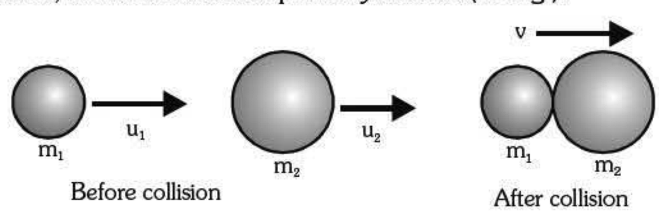
  1 kW h = 1 kW × 1 h = 1000 W × 3600 s = 3600000 J or **1 kWh = 3.6 × 10⁶ J**.

■ **Collisions :** A collision is said to have occurred if two bodies or particles physically collide against each other. In any collision total momentum and total energy is conserved.

- For any type of collision, the total momentum of the system just before the collision equals the total momentum just after the collision. The total kinetic energy, on the other hand, is generally not conserved in a collision because some of the kinetic energy is converted to heat energy, sound energy, and the work needed to permanently deform the objects involved, such as cars in a car crash.

- **Inelastic collision :** A collision in which momentum is conserved, but kinetic energy is not is called an inelastic collision.

  - The collision of a rubber ball with a hard surface is inelastic, because some of the kinetic energy is lost when the ball is deformed during contact with the surface.
  - **Perfectly inelastic collision :** When two objects collide and stick together, the collision is called **perfectly inelastic**. For example, if two pieces of putty collide, they stick together and move with some common velocity after the collision. If a meteorite collides head on with the Earth, it becomes buried in the Earth and the collision is considered perfectly inelastic.
  - In a perfectly inelastic collision, the loss of kinetic energy is maximum. But, only in rare cases, all the initial kinetic energy is lost in a perfectly inelastic collision.
  - Consider two objects having masses $m_1$ and $m_2$ moving with known initial velocity components $u_1$ and $u_2$ along a straight line. If the two objects collide head-on, stick together, and move with a common velocity v after the collision, then the collision is perfectly inelastic (see fig.).




Perfectly inelastic collision

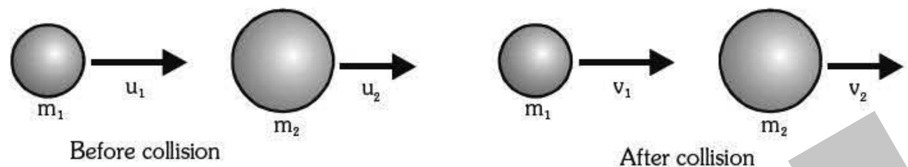
According to principle of conservation of momentum,

Initial momentum = Final momentum

or $m_1u_1 + m_2u_2 = m_1v + m_2v$

or $\boxed{v = \dfrac{m_1u_1 + m_2u_2}{m_1 + m_2}}$

- **Elastic collision :** An elastic collision is defined as one in which both momentum and kinetic energy are conserved.
  - Billiard ball collisions and the collisions of air molecules with the walls of a container at ordinary temperatures are highly elastic. Macroscopic collisions such as those between billiard balls are only approximately elastic, because some loss of kinetic energy takes place—for example, in the clicking sound when two balls strike each other.
  - Perfectly elastic collisions also occur, between atomic and subatomic particles.
- **Elastic collision in one dimension :** Let us consider two spheres of masses $m_1$ and $m_2$ moving with initial velocities $u_1$ and $u_2$ respectively. They collide head-on i.e., their velocity vectors are along the line joining their geometric centers. They move along the same straight line after collision. Let after collision the velocities of $m_1$ and $m_2$ become $v_1$ and $v_2$ respectively (see fig.).

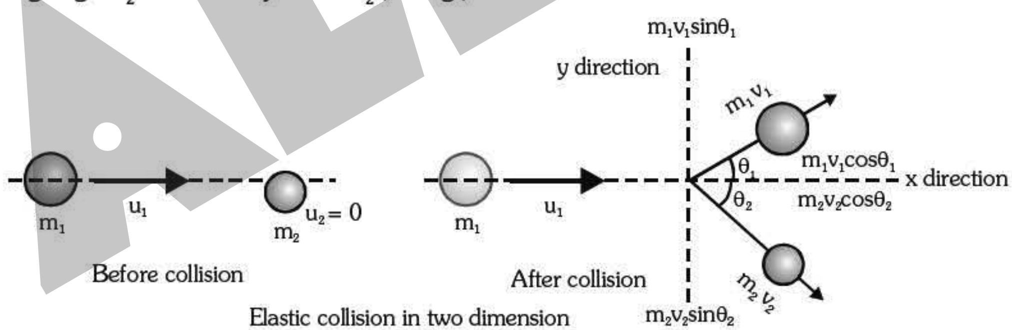



Elastic collision in one dimension

Using conservation of momentum and conservation of kinetic energy, we can derive the formulae for $v_1$ and $v_2$ which are as given below,

$$\boxed{v_1 = \left(\frac{m_1 - m_2}{m_1 + m_2}\right)u_1 + \left(\frac{2m_2}{m_1 + m_2}\right)u_2} \qquad \boxed{v_2 = \left(\frac{2m_1}{m_1 + m_2}\right)u_1 + \left(\frac{m_2 - m_1}{m_1 + m_2}\right)u_2}$$

- **Elastic collision in two dimension :** Let us consider two spheres of masses $m_1$ moving with initial velocity $u_1$ and mass $m_2$ is at rest i.e., $u_2 = 0$. They collide obliquely i.e., their velocity vectors are not along the line joining their geometric centers. They move along the two different lines after collision i.e., their motion after collision is in two dimensions. Let after collision the velocities of $m_1$ and $m_2$ become $v_1$ and $v_2$ respectively (see fig.). Let $m_1$ moves along a line making angle $\theta_1$ with velocity vector $v_1$ and $m_2$ moves along a line making angle $\theta_2$ with velocity vector $v_2$ (see fig.).




Elastic collision in two dimension

**Conservation of momentum :**

x direction : Initial momentum = Final momentum

$m_1u_1 = m_1v_1\cos\theta_1 + m_2v_2\cos\theta_2$ ----- (1)

y direction : Initial momentum = Final momentum

$0 = m_1v_1\sin\theta_1 - m_2v_2\sin\theta_2$ ----- (2)

**Conservation of kinetic energy :**

Initial kinetic energy = Final kinetic energy

$$\frac{1}{2}mu^2 = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 \text{ ----- (3)}$$

Using eqs.(1), (2) and (3), we can solve for the unknowns in the problem based on collision in two dimensions.

# EXERCISE UNIT –2

## TOPICS : FORCE & NEWTON'S LAWS OF MOTION ; DYNAMICS OF CIRCULAR MOTION ; WORK, ENERGY & POWER

### NEWTON'S LAWS OF MOTION

**1.** A boy sitting on the top most berth in the compartment of a train which is just going to stop on a railway station, drops an apple aiming at the open hand of his brother sitting vertically below his hands at a distance of about 2 m. The apple will fall-
(1) precisely on the hand of his brother
(2) slightly away from the hand of his brother in the direction of motion of the train
(3) slightly away from the hand of his brother in the direction opposite to the direction of motion of the train
(4) none of the above

**2.** The engine of a car produces acceleration $4\ m/s^2$ in the car. If this car pulls another car of same mass. What will be the acceleration produced-
(1) $1\ m/s^2$ (2) $1.5\ m/s^2$
(3) $2\ m/s^2$ (4) $4\ m/s^2$

**3.** A force vector applied on a mass is represented as $\vec{F} = 6\hat{i} - 8\hat{j} + 10\hat{k}$ and accelerates with $1\ m/s^2$. What will be the mass of the body-
(1) $10\sqrt{2}$ kg (2) $2\sqrt{10}$ kg
(3) 10 kg (4) 20 kg

**4.** A vehicle of 100 kg is moving with a velocity of 5 m/sec. To stop it in $\frac{1}{10}$ s, the required force in opposite direction is-
(1) 5000 newton (2) 500 newton
(3) 50 newton (4) 1000 newton

**5.** A force of 6N acts on a body at rest of mass 1 kg. During this time, the body attains a velocity of 30 m/s. The time for which the force acts on the body is-
(1) 10 seconds (2) 8 seconds
(3) 7 seconds (4) 5 seconds

**6.** A force of 50 dynes is acted on a body of mass 5 g which is at rest for an interval of 3 sec., then impulse is-
(1) $0.15 \times 10^{-13}$ Ns (2) $0.98 \times 10^{-3}$ Ns
(3) $1.5 \times 10^{-3}$ Ns (4) $2.5 \times 10^{-3}$ Ns

**7.** A truck of mass 500 kg moving with constant speed 10 m/s. If sand is dropped into the truck at the constant rate 10 kg/min., the force required to maintain the motion with constant velocity is-
(1) $\frac{5}{3}$ N (2) $\frac{5}{4}$ N (3) $\frac{7}{5}$ N (4) $\frac{3}{2}$ N

**8.** A 1 kg particle strikes a wall with velocity 1 m/s at an angle of 30° with the normal to the wall and reflects at the same angle. If it remain in contact with wall for 0.1 s, then the force is :-
(1) 0 (2) $10\sqrt{3}$ N
(3) $30\sqrt{3}$ N (4) $40\sqrt{3}$ N

**9.** A cricketer catches a ball of mass 150 gm in 0.1 sec moving with speed 20 m/s, then he experiences force of-
(1) 300 N (2) 30 N (3) 3 N (4) 0.3 N

**10.** A force $\vec{F} = 6t^2\hat{i} + 4t\hat{j}$, is acting on a particle of mass 3 kg then what will be velocity of particle at t = 3 sec. if at t = 0, particle is at rest
(1) $18\hat{i} + 6\hat{j}$ (2) $18\hat{i} + 12\hat{j}$
(3) $12\hat{i} + 6\hat{j}$ (4) None

**11.** A force 10 N acts on a body of mass 20 kg for 10 sec. Change in its momentum is-
(1) 5 kg m/s (2) 100 kg m/s
(3) 200 kg m/s (4) 1000 kg m/s

**12.** The linear momentum P of a body varies with time and is given by the equation $P = x + yt^2$ where x and y are constants. The net force acting on the body for a one dimensional motion is proportional to :-
(1) $t^2$ (2) a constant (3) $\frac{1}{t}$ (4) t

**13.** A machine gun is mounted on a 2000 kg. car on a horizontal frictionless surface. At some instant the gun fires bullets of mass 10 gm with a velocity of 500 m/sec. with respect to the car. The number of bullets fired per second is ten. The average thrust on the system is-
(1) 550 newton (2) 50 newton
(3) 250 newton (4) 250 dyne

**14.** An object with a mass 10 kg moves at a constant velocity of 10 m/sec. A constant force then acts for 4 second on the object and gives it a speed of 2 m/sec. in opposite direction. The acceleration produced is-

(1) 3 m/sec² (2) –3 m/sec²
(3) 0.3 m/sec² (4) –0.3 m/sec²

**15.** At a place where the acceleration due to gravity is 10 m $sec^{-2}$ a force of 5 kg-wt acts on a body of mass 10 kg initially at rest. The velocity of the body after 4 second is-

(1) 5m $sec^{-1}$ (2) 10 m $sec^{-1}$
(3) 20 m $sec^{-1}$ (4) 50 m $sec^{-1}$

**16.** Gravels are dropped on a conveyor belt at the rate of 0.5 kg/sec. The extra force required in newtons to keep the belt moving at 2 m/sec. is-

(1) 1 N (2) 2 N (3) 4 N (4) 0.5 N

**17.** A man is standing at a spring platform. Reading of spring balance is 60 kg wt. If man jumps outside platform, then reading of spring balance.

(1) First increases then decreases to zero
(2) Decreases
(3) Increases
(4) Remains same

**18.** A cold soft drink is kept on the balance. When the cap is open, then the weight-

(1) Increases
(2) Decreases
(3) First increases then decreases
(4) Remains same

**19.** As an inclined plane is made slowly horizontal by reducing the value of angle θ with horizontal, the component of weight parallel to the plane of a block resting on the inclined plane-

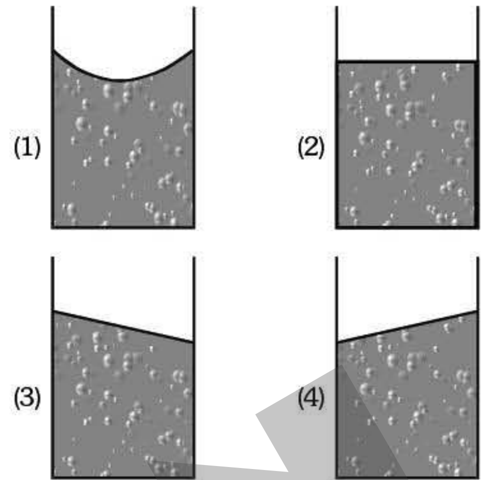
(1) decreases
(2) remains same
(3) increases
(4) increases if the plane is smooth

**20.** A mass is suspended from the roof of a car by a string. While the car has a constant acceleration a, the string makes an angle of 60° with the vertical. If g = 10 m/$s^2$, the value of a is-

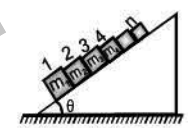
(1) $10(3)^{1/2}$ m/s² (2) $\left(\frac{10}{3}\right)^{1/2}$ m/s²

(3) 5 m/s² (4) $5(3)^{1/2}$ m/s²

**21.** A beaker half-filled with water is accelerated towards the left on a straight horizontal path. The surface of the liquid inside the moving beaker is represented by the figure-




**22.** n-blocks of different masses are placed on the frictionless inclined plane in contact. They are released at the same time. The force of interaction between (n-1)$^{th}$ and n$^{th}$ blocks is




(1) $(m_{n-1} - m_n)$ g sin θ
(2) zero
(3) mng cosθ
(4) none of these

**23.** A rope of length L is pulled by a constant force F. What is the tension in the rope at a distance x from the end where the force is applied.

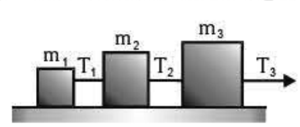
(1) $\frac{FL}{x}$ (2) $\frac{F(L-x)}{L}$ (3) $\frac{FL}{L-x}$ (4) $\frac{Fx}{L-x}$

**24.** A block of mass M is pulled along a horizontal frictionless surface by a rope of mass m. If a force P is applied at the free end of the rope, the force exerted by the rope on the block is-

(1) P (2) $\frac{PM}{M+m}$

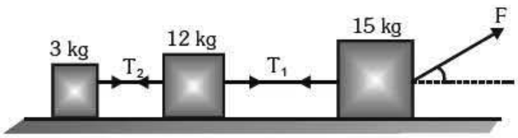
(3) $\frac{Pm}{M+m}$ (4) $\frac{Pm}{M-m}$

**25.** Three blocks are connected as shown in fig., on a horizontal frictionless table and pulled to the right with a force $T_3$ = 60 N. If $m_1$ = 10 kg. $m_2$ = 20 kg. and $m_3$ = 30 kg, the tension $T_2$ is-



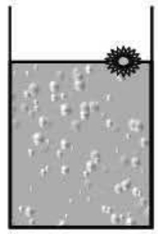

(1) 10 N (2) 20 N
(3) 30 N (4) 60 N

**26.** In fig. if the surfaces are frictionless the ratio $T_1:T_2$ is-




(1) $\sqrt{3}$ : 2 (2) 1 : $\sqrt{3}$
(3) 1 : 5 (4) 5 : 1

**27.** A body floats in liquid contained in a beaker. If the whole system (shown in fig.) falls under gravity then the up-thrust on the body is-



(1) 2 mg
(2) zero
(3) mg
(4) less than mg

**28.** A man weighs 80 kg. He stands on a weighing scale in a lift which is moving upwards with a uniform acceleration of 5 $m/s^2$. What would be the reading on the scale- (g = 10 $m/s^2$)
(1) 1200 N (2) Zero
(3) 400 N (4) 100 N

**29.** If a 5 kg mass is suspended by a spring balance in a lift which is accelerating downwards at 10 $m/s^2$. The reading of the balance- (g=10$m/s^2$)
(1) more than 5 kg weight
(2) is less than 5 kg weight
(3) is equal to 5 kg weight
(4) zero

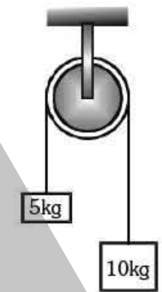
**30.** The ratio of the weight of a man in a stationary lift and in a lift accelerating downwards with a uniform accleration 'a' is 3 : 2. The accleration of the lift is-
(1) $\frac{g}{3}$ (2) $\frac{g}{2}$ (3) g (4) 2g

**31.** A lift is moving up with an acceleration of 3.675 $m/sec^2$. The weight of a man-
(1) increases by 37.5% (2) decreases by 37.5%
(3) increases by 137.5% (4) remains the same

**32.** The acceleration with which an object of mass 100 kg be lowered from a roof using a cord with a breaking strength of 60 kg weight without breaking the rope is-
(1) 2 $m/sec^2$ (2) 4 $m/sec^2$
(3) 6 $m/sec^2$ (4) 10 $m/sec^2$

**33.** A block of mass 2 kg is joined to a body of mass 1 kg. Block is placed on a horizontal table and the string moves over a pulley, which is at the edge of the table. Mass of 1 kg is suspended by the string. If table is frictionless then acceleration of block and tension in string are respectively-
(1) 4.38 $m/s^2$, 6.54 N (2) 4.38 $m/s^2$, 9.86 N
(3) 3.27 $m/s^2$, 6.54 N (4) 3.27 $m/s^2$, 9.86 N

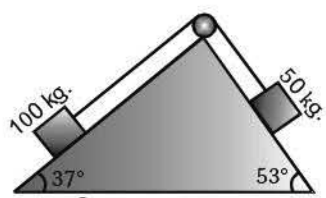
**34.** Two masses of 5 kg and 10 kg are connected to a pulley as shown. What will be the acceleration if the pulley is set free? [g = acceleration due to gravity]




(1) g
(2) $\frac{g}{2}$
(3) $\frac{g}{3}$
(4) $\frac{g}{4}$

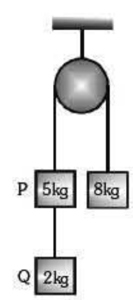
**35.** A light string passing over a smooth light pulley connects two blocks of masses $m_1$ and $m_2$ (vertically). If the acceleration of the system is $\left(\frac{g}{8}\right)$, then the ratio of masses is-
(1) 8 : 1 (2) 9 : 7 (3) 4 : 3 (4) 5 : 3

**36.** Two blocks are connected by a cord passing over a small frictionless pulley and resting on frictionless planes as shown in the figure. The accleration of the blocks is-




(1) 0.33 $m/s^2$ (2) 0.66 $m/s^2$
(3) 1 $m/s^2$ (4) 1.32 $m/s^2$

**37.** In the following fig., two masses P and Q are joined with a string. The tension in the string in between P and Q in newton will be-




(1) g
(2) $\frac{g}{15}$
(3) $\frac{16g}{15}$
(4) $\frac{32g}{15}$

**38.** A disc of mass 10 gm. is kept floating horizontally by throwing 10 marbles/sec against it from below. If the mass of each marble is 5 g; calculate the velocity with which the marbles are striking the disc. Assume that the marbles strike the disc normally and rebound downward with the same speed.

(1) 9.8 m/s (2) 98 m/s

(3) 0.98 m/s (4) .098 m/s

**39.** A truck carrying sand is moving on a smooth horizontal road with a uniform speed u. If a mass $\Delta m$ of sand leaks in a time $\Delta t$ from the bottom of the truck, the force needed to keep the truck moving at its uniform speed u is given by-

(1) $\frac{\Delta mu}{\Delta t}$ (2) $\frac{\Delta mu}{2\Delta t}$ (3) $\frac{\Delta mu^2}{\Delta t}$ (4) zero

**40.** A man of mass 60 kg record his wt. on a weighing machine placed inside a lift. The ratio of weights of man recorded when lift is ascending up with a uniform speed of 2 m/s to when it is descending down with a uniform speed of 4 m/s will be-

(1) 0.5 (2) 1

(3) 2 (4) None

**41.** An empty plastic box of mass m is found to accelerate up at the rate of g/6, when placed deep inside water. How much sand should be put inside the box so that it may accelerate down at the rate of g/6 ?

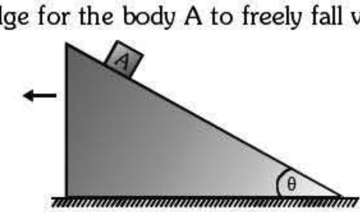
(1) 2m/3 (2) 2m/5 (3) m/5 (4) 6m/7

**42.** A spring toy weighing 1 kg on a spring balance suddenly jumps upward. A boy standing near the toy notices that the scale of the balance reads 1.05 kg. In this process the maximum acceleration of the toy is- (g = 10m $sec^{-2}$)

(1) 0.05 m $sec^{-2}$ (2) 0.5 m $sec^{-2}$

(3) 1.05 m $sec^{-2}$ (4) 1 m $sec^{-2}$

**43.** Body A is placed on frictionless wedge making an angle θ with the horizontal. The horizontal acceleration towards left to be imparted to the wedge for the body A to freely fall vertically, is-




(1) g sin θ (2) g cos θ

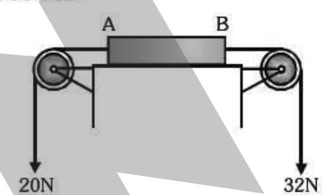
(3) g tan θ (4) g cot θ

**44.** An object kept on a smooth inclined plane of 1 in $\ell$ can be kept stationary relative to the incline by giving a horizontal acceleration of ........... to the inclined plane-

(1) $\frac{g}{\sqrt{\ell^2-1}}$ (2) $\frac{g}{\sqrt{1-\ell^2}}$

(3) $g\sqrt{\ell^2-1}$ (4) $\frac{1}{g\sqrt{1-\ell^2}}$

**45.** Figure shows a uniform rod of mass 3 kg and of length 30 cm. The strings shown in figure are pulled by constant forces of 20 N and 32 N. The acceleration of the rod is-



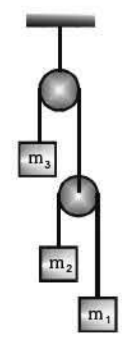

(1) 2 $m/s^2$

(2) 3$m/s^2$

(3) 4$m/s^2$

(4) 6$m/s^2$

**46.** Three masses $m_1$, $m_2$ and $m_3$ are attached to a string pulley system as shown. All three masses are held at rest and then released. To keep $m_3$ at rest, the condition is :-



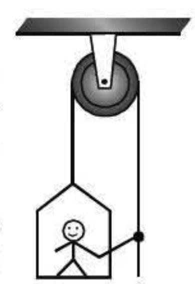

(1) $\frac{1}{m_3}=\frac{1}{m_1}+\frac{1}{m_2}$

(2) $m_1 + m_2 = m_3$

(3) $\frac{4}{m_3}=\frac{1}{m_1}+\frac{1}{m_2}$

(4) $\frac{1}{m_1}+\frac{2}{m_2}=\frac{3}{m_3}$

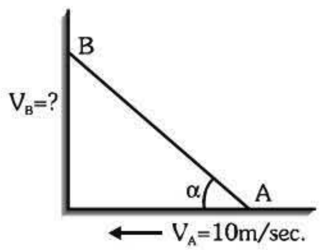
**47.** The following figure represents a painter in a swing by the side of a buillding. When the painter pulls the string then the force applied on the surface is 450 N, whereas the weight of painter is 1000 N. If the weight of swing is 250 N then the acceleration produced in the swing will be-



(1) 4 $m/s^2$ (2) 2 $m/s^2$

(3) 5 $m/s^2$ (4) 6 $m/s^2$

**48.** A rigid rod is placed against the wall as shown in figure. When its velocity of lower end is 10 m/s and its base makes an angle $\alpha = 60°$ with horizontal, then the vertical velocity of its end B will be :



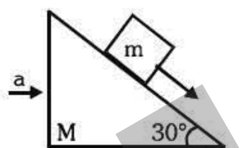

(1) $10\sqrt{3}$

(2) $\frac{10}{\sqrt{3}}$

(3) $5\sqrt{3}$

(4) $\frac{5}{\sqrt{3}}$

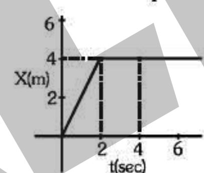
**49.** A small mass m is slipping over a frictionless incline (as shown in the figure) made of wood of mass M. The acceleration by which the incline should be pushed so that block m remains stationary is :




(1) $\frac{g}{\sqrt{3}}$ (2) $\frac{2}{\sqrt{3}}g$

(3) $\frac{g}{\sqrt{2}}$ (4) $\frac{\sqrt{3}}{2}g$

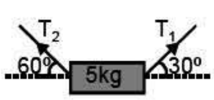
**50.** In the figure given below, the position–time graph of a particle of mass 0·1 kg is shown. The impulse at t=2 sec is –




(1) 0·2 $kgmsec^{-1}$
(2) –0·2 $kgmsec^{-1}$
(3) 0·1 $kgmsec^{-1}$
(4) –0·4 $kgmsec^{-1}$

**51.** A wide hose pipe is held horizontally by a fireman, it delivers water through a nozzle at one litre per second. On increasing the pressure, this increases to two litres per second. The fireman has now to
(1)Push forward twice as hard
(2) Push forward four times as hard
(3) Push backward four times as hard
(4) Push back ward twice as hard

**52.** A body of mass 5kg is suspended by string making angle 60º & 30º with horizontal then -

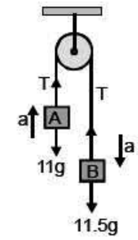



(a) $T_1$ = 25N (b) $T_2$ = 25 N

(c) $T_1 = 25\sqrt{3}$N (d) $T_2 = 25\sqrt{3}$N

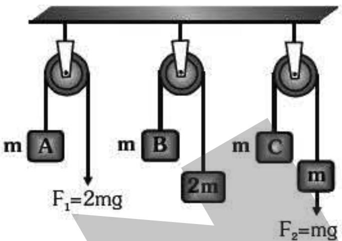
(1) a, b (2) a, d (3) c, d (4) b, c

**53.** In fig. speed of each particle after 4 sec. -




(1) 0.872 m/s
(2) 8.72 m/s
(3) 0.218 m/s
(4) 2.18 m/s

**54.** In the figure, the block A, B and C each of mass m have accelerations $a_1$, $a_2$ and $a_3$ respectively. $F_1$ and $F_2$ are external forces of magnitude 2 mg and mg respectively. Then




(1) $a_1 = a_2 = a_3$ (2) $a_1 > a_3 > a_2$

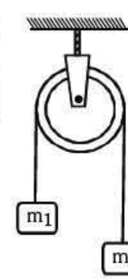
(3) $a_1 = a_2$, $a_2 > a_3$ (4) $a_1 > a_2$ , $a_2 = a_3$

**55.** A bullet is fired from a gun. The force on the bullet is given by $F = 600 - 2 \times 10^5 t$,where F is in N and t in sec. The force on bullet becomes zero as soon as it leaves barrel. What is average impulse imparted to bullet-
(1) 9 Ns (2) zero (3) 0.9 Ns (4) 1.8 Ns

**56.** A rocket which has a mass of $3.5 \times 10^4$ kg is blasted upwards with an initial acceleration of 10 $m/s^2$ Then the initial thrust of the blast is-
(1) $3.5 \times 10^5$ N (2) $7.0 \times 10^5$ N
(3) $14.0 \times 10^5$ N (4) $1.75 \times 10^5$ N

**57.** A machine gun fires a bullet of mass 40 g with a velocity 1200 $ms^{-1}$. The man holding it, can exert maximum force of 144 N on the gun. How many bullets can he fire per second at the most?
(1) One (2) Four (3) Two (4) Three

**58.** Two masses $m_1$ = 5 kg and $m_2$ = 4.8 kg tied to a string are hanging over a light frictionless pulley. What is the acceleration of the masses ? (g = 9.8 $m/s^2$)



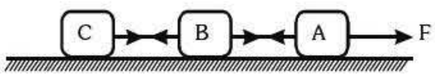

(1) 0.2 $m/s^2$
(2) 9.8 $m/s^2$
(3) 5 $m/s^2$
(4) 4.8 $m/s^2$

**59.** A player caught a cricket ball of mass 150 g moving at a rate of 20 m/s. If the catching process is completed in 0.1 s., the force of the blow exerted by the ball on the hand of the player is equal to-
(1) 150 N (2) 3 N (3) 30 N (4) 300 N

**60.** If a body losses half of its velocity on penetrating 3 cm in a wooden block, then how much will it penetrate more before coming to rest?
(1) 1 cm (2) 2 cm (3) 3 cm (4) 4 cm

**61.** When forces $F_1$, $F_2$, $F_3$ are acting on a particle of mass m such that $F_2$ and $F_3$ are mutually perpendicular, then the particle remains stationary. If the force $F_1$ is now removed then the acceleration of the particle is-
(1) $F_1/m$ (2) $F_2F_3/mF_1$
(3) $(F_2 - F_3)/m$ (4) $F_2/m$

**62.** Three identical blocks of masses m = 2 kg are drawn by a force F with an acceleration of $0.6\ ms^{-2}$ on a frictionless surface, then what is the tension (in N) in the string between the blocks B and C




(1) 9.2 (2) 1.2 (3) 4 (4) 9.8

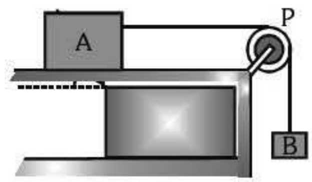
**FRICTION**

**63.** Mark the correct statements about the friction between two bodies
[a] static friction is always greater than the kinetic friction
[b] coefficient of static friction is always greater than the coefficient of kinetic friction
[c] limiting friction is always greater than the kinetic friction
[d] limiting friction is never less than static friction
(1) b, c, d (2) a, b, c (3) a, c, d (4) a, b, d

**64.** Which of the following statements is not true-
(1) The coefficient of friction between two surfaces increases as the surface in contact are made rough
(2) The force of static friction acts in a direction opposite to the applied force
(3) Rolling friction is greater than sliding friction
(4) The coefficient of friction between wood and wood is less than 1

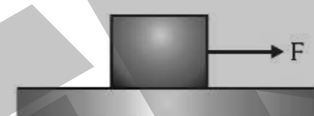
**65.** The brakes of a car moving at 20 m/sec along a horizontal road are suddenly applied and it comes to rest after travelling some distance if the coefficient of friction between the tyres and the road is 0.90 and it is assumed that all four tyres behave identically, the shortest distance the car would travel before coming to a stop is-
(1) 2.27 m (2) 11.35 m
(3) 22.7 m (4) 4.54 m

**66.** The blocks A and B are arranged as shown in the figure. The pulley is frictionless. The mass of A is 10 kg. The coefficient of friction between block A and horizontal surface is 0.20. The minimum mass of B to start the motion will be-




(1) 2 kg (2) 0.2 kg (3) 5 kg (4) 10 kg

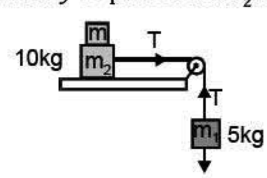
**67.** In the fig. shown, a block of weight 10 N is resting on a horizontal surface. The coefficient of static friction between the block and the surface $\mu_s = 0.4$. A force of 3.5 N will keep the block in uniform motion, once it has been set in motion. A horizontal force of 3N is applied to the block, then the block will-




(1) Move over the surface with constant velocity.
(2) Move having accelerated motion over the surface.
(3) Will not move.
(4) First it will move with a constant velocity for some time and then will have accelerated motion.

**68.** A lift is moving downwards with an acceleration equal to the acceleration due to gravity. A body of mass M kept on the floor of the lift is pulled horizontally, if the coefficient of friction is μ, then the frictional resistance offered by the body is
(1) Mg (2) μMg (3) 2μMg (4) zero

**69.** Two masses $m_2$ = 10kg and $m_1$ = 5kg are connected by a string passing over a pulley as shown. If the coefficient of friction be 0.15, then the minimum weight that may be placed on $m_2$ to stop motion is -



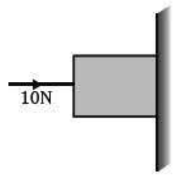

(1) 18.7 kg
(2) 23.3 kg
(3) 32.5 kg
(4) 44.3 kg

**70.** A box is lying on an inclined plane. If the box starts sliding when the angle of inclination is 60°, then the coefficient of static friction of the box and plane is-
(1) 2.732 (2) 1.732 (3) 0.267 (4) 0.176

**71.** A block of mass 0.1 kg is held against a wall by applying a horizontal force of 5N on the block. If the co-efficient of friction between the block and the wall is 0.5, the magnitude of frictional force acting on the block is-

(1) 2.5 N (2) 0.98 N
(3) 4.9 N (4) 0.49 N

**72.** A horizontal force of 10 N is necesssry to just hold a block stationary against a wall. The coefficient of friction between the block and the wall is 0.2. The weight of the block is-




(1) 100 N
(2) 2 N
(3) 20 N
(4) 50 N

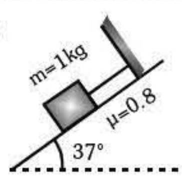
**73.** A 20 kg block is initially at rest. A 70 N force is required to set the block in motion. After the motion, a force of 60 N is applied to keep the block moving with constant speed. The coefficient of static friction is-

(1) 0.6 (2) 0.52 (3) 0.44 (4) 0.35

**74.** An insect crawls up a hemispherical surface very slowly, figure. The coefficient of friction between the insect and the surface is $\frac{1}{3}$. If the line joining the centre of the hemispherical surface to the insect makes an angle $\alpha$ with the vertical, the max. possible value of $\alpha$ is given by-

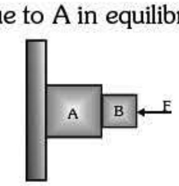

(1) $\cot \alpha = 3$
(2) $\sec \alpha = 3$
(3) $\text{cosec}\ \alpha = 3$ (4) None

**75.** For the arrangement in figure, the tension in the string to prevent it from sliding




(1) 6 N
(2) 6.4 N
(3) 0.4 N
(4) zero

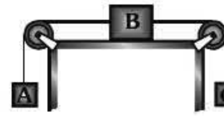
**76.** Consider the situation shown in figure The wall is smooth but the surface of A and B in contact are rough. The friction on B due to A in equilibrium-




(a) is upward
(b) is downward
(c) is zero
(d) the system cann't remain is equilibrium

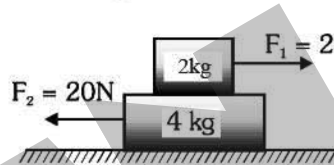
(1) only a (2) only b
(3) only d (4) c and d both

**77.** Block A has a mass of 2 kg and block B has a mass of 20 kg if the coefficient of kinetic friction between block B and the horizontal surface is 0.1, and B is accelerating towards the right with $a = 2\ m/s^2$, then the mass of the block C will be




(1) 15 kg
(2) 12.5 kg
(3) 5.7 kg
(4) 10.5 kg

**78.** In the arrangement shown in figure, coefficient of friction between the two blocks is $\mu = \frac{1}{2}$. The force of friction acting between the two blocks is:-




(1) 8 N (2) 10 N (3) 6 N (4) 4 N

**79.** A block of mass 2 kg is projected upwards along a 30° incline with an initial velocity of 22 m/s. The coefficient of friction between the block and the plane is 0.3. The block moves up the plane a distance of-

(1) 6.8 m (2) 8.6 m (3) 32 m (4) 86 m

**80.** A horizontal force F is exerted on a 20 kg block to push it up an inclined plane having an inclination of 30°. The frictional force retarding the motion is 80N. For the acceleration of the moving block to be zero, the force F must be-

(1) 206 N (2) 602 N
(3) 620 N (4) 260 N

**81.** A smooth block is released at rest on a 45° incline and then slides a distance d. The time taken to slide is n times as much to slide on rough incline than on a smooth incline. The coefficient of friction is-

(1) $\mu_k = 1 - \frac{1}{n^2}$ (2) $\mu_k = \sqrt{1-\frac{1}{n^2}}$

(3) $\mu_s = 1 - \frac{1}{n^2}$ (4) $\mu_s = \sqrt{1-\frac{1}{n^2}}$

**82.** Consider a car moving on a straight road with a speed of 100 m/s. The distance at which car can be stopped, is : $[\mu_k = 0.5]$

(1) 800 m (2) 1000 m
(3) 100 m (4) 400 m

## Work Power Energy

**83.** A body which is constrained to move along Y–direction is acted upon by a force $\vec{F} = (-2\hat{i} + 15\hat{j} + 6\hat{k})N$. The work done by this force in displacing the body by 10m along Y–axis is-

(1) 105 J (2) 150 J (3) 250 J (4) 100 J

**84.** A particle moves from position $\vec{r_1} = 3\hat{i} + 2\hat{j} - 6\hat{k}$ to position $\vec{r_2} = 14\hat{i} + 13\hat{j} + 9\hat{k}$ under the action of a force $4\hat{i} + \hat{j} + 3\hat{k}$ newton. Find the work done-

(1) 10 J (2) 100 J (3) 0.01 J (4) 1 J

**85.** The mass of the bob of a simple pendulum is m and it can be raised maximum up to height h. The work done by gravity in moving it from one extreme to other is-

(1) 2mgh (2) mgh (3) 3mgh (4) Zero

**86.** A body of mass 100 gm is rotating in a circular path of radius r with constant speed. The work done in one complete revolution is-

(1) 100 r J (2) $\frac{r}{100}$J (3) $\frac{100}{r}$J (4) zero

**87.** A particle of mass m is moving along a circular path of radius r and F is the centripetal force acting on it. The work done in moving it along a semicircular path is-

(1) zero (2) F.r (3) 2Fr (4) Fmr

**88.** Under the effect of a force of 5 newtons a body travels a distance of 10 meter along a straight line and the work done in the process is 25 joule. The angle between the force and the displacement is-

(1) 0° (2) 30° (3) 60° (4) 90°

**89.** Find the workdone in moving a 50 kg. block through a horizontal distance of 10 m. by applying a force of 100 N which makes an angle of 60° with the horizontal-

(1) 50 Joule (2) 50 ergs
(3) 500 Joule (4) 500 ergs

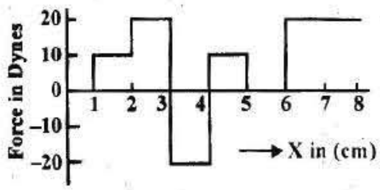
**90.** A man weighing 50 Kg carries a load of 10 Kg to the top of the building in 4 minutes. The work done by the man is $6 \times 10^4$ J. If he carries the same load in 8 minutes, the work done by the man will be-

(1) $1.5 \times 10^4$ J (2) $3 \times 10^4$ J
(3) $6 \times 10^4$ J (4) $12 \times 10^4$ J

**91.** A person holds a bucket of weight 60N. He walks 7m along the horizontal and then climbs a vertical distance of 5m. The work done by the man is-

(1) 300 J (2) 420 J
(3) 720 J (4) None of the above

**92.** The relationship between force and position is shown in fig.(in one dimensional case). The work done by the force in displacing a body from x = 1 cm to x = 5 cm is-

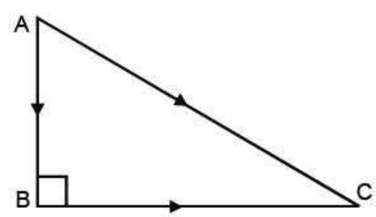



(1) 20 ergs (2) 60 ergs (3) 70 ergs (4) 700 ergs

**93.** The amount of work done in stretching a spring from a stretched length of 10 cm to a stretched length of 20 cm is-

(1) Equal to the work done in stretching it from 20 cm to 30 cm.
(2) Less than the work done in stretching it from 20 cm to 30 cm.
(3) More than the work done in stretching it from 20 cm to 30 cm.
(4) Equal to the work done in stretching it from 0 to 10 cm.

**94.** The work done in moving a particle under the effect of a conservative force, from position A to B is 3 joule and from B to C is 4 joule. The work done in moving the particle from A to C is-




(1) 5 joule (2) 7 joule (3) 1 joule (4) –1 joule

**95.** A bomb at rest has mass 60 kg. It explodes and a fragment of 40 kg has kinetic energy 96 joule. Then kinetic energy of other fragment is-

(1) 180 J (2) 190 J (3) 182 J (4) 192 J

**96.** The force acting on a body is inversely proporional to its speed. The kinetic energy of the body is-

(1) Consant
(2) Inversley proportional to time
(3) Directly proportional to time
(4) None of the above

**97.** A particle A is projected vertically upwards. Another particle B is projected at an angle of 45°. Both reach the same height. The ratio of the initial kinetic energy of A to that of B is-

(1) 1 : 2  (2) 2 : 1

(3) 1 : $\sqrt{2}$  (4) $\sqrt{2}$ : 1

**98.** Two springs of spring constants 1500 N/m and 3000 N/m respectively are stretched with the same force. They will have potential energy in the ratio-

(1) 4 : 1  (2) 1 : 4

(3) 2 : 1  (4) 1 : 2

**99.** If a spring extends by x on loading, then the energy stored by the spring is- (T is the tension in the spring and K is force constant)

(1) $\frac{2x}{T^2}$  (2) $\frac{T^2}{2K}$  (3) $\frac{2K}{T^2}$  (4) $\frac{T^2}{2x}$

**100.** Under the application of a constant force, starting from rest and moving for some fixed distance, the kinetic energy of a mass m is proportional to-

(1) $\sqrt{m}$

(2) Does not depend on m

(3) $1/\sqrt{m}$

(4) m

**101.** The energy required to accelerate a car from 10 m/s to 20 m/s is how many times the energy required to accelerate the car from rest to 10 m/s-

(1) Equal  (2) 4 times

(3) 2 times  (4) 3 times

**102.** A boy is sitting on a swing at a maximum height of 5m above the ground. When the swing passes through the mean position which is 2m above the ground its velocity is approximately-

(1) 7.6 m/sec  (2) 9.8 m/sec

(3) 6.26 m/sec  (4) None of these

**103.** A mass of 0.5 kg moving with a speed of 1.5 m/s on a horizontal smooth surface, collides with a nearly weightless spring of force constant k = 50 N/m. The maximum compression of the spring wouldbe-

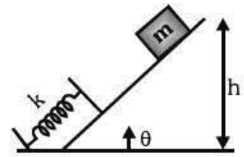
(1) 0.15 m  (2) 0.12 m

(3) 1.5 m  (4) 0.5 m

**104.** A block of mass m slips down an inclined plane as shown in the figure and it presses a spring lying at the bottom. If the length of the spring $\ell >>$ h and spring constant is K the compression in the spring will be-

1) $\sqrt{\frac{mgh}{k}}$  (2) $\sqrt{\frac{2mgh}{k}}$

(3) $\sqrt{\frac{gh}{mk}}$  (4) $\sqrt{\frac{2gh}{mk}}$




**105.** Under the action of a central force, there is a conservation of -

(1) Angular momentum only

(2) Mechanical energy only

(3) Angular momentum and mechanical energy

(4) Neither angular momentum nor mechanical energy

**106.** A heavy stone is thrown from a cliff of height h with a speed v. The stone will hit the ground with maximum speed if it is thrown-

(1) Vertically downward

(2) Vertically upward

(3) Horizontally

(4) The speed does not depend on the initial direction

**107.** The kinetic energy of a body decreases by 19% what is the percentage decrease in momentum-

(1) 20 %  (2) 15 %  (3) 10 %  (4) 5 %

**108.** The negative of the work done by the conservative internal forces on a system equals the change in-

(1) Potential energy  (2) Kinetic energy

(3) Total energy  (4) None of these

**109.** Work-energy theorem is valid in the presence of-

(1) All types of forces

(2) Internal force only

(3) Conservative forces only

(4) Non-conservative forces only

**110.** A man throws the bricks to the height of 12 m where they reach with a speed of 12 m/s. If he throws the bricks such that they just reach this height, what percentage of energy will he save-

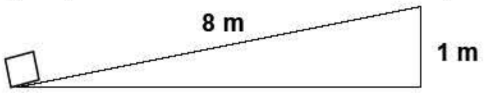
(1) 19%  (2) 76%  (3) 38%  (4) 57%

**111.** A truck of mass 2800 kg is moving with a speed of 15 m/s. A fricitonal retarding force of 500N and a forward force of 1200 N are acting on it, then in 10 sec it shall travel a distance of-

(1) 156 m  (2) 122.8 m

(3) 162.5 m  (4) 118 m

**112.** A mass of 2 kg rests on an inclined planes of gradient 1 in 8 as shown. The work done in sliding it from the lowest point of the incline to the highest point, if the coefficient of friction is 0.2, is-




(1) 192 J (2) 19.2 J
(3) 48 J (4) 52 J

**113.** With how much velocity a block of mass 2kg should move on a friction less surface so as to compress a spring with force constant 2 newton/meter by 4 meter-
(1) 4 m/s (2) 16 m/s
(3) 2 m/s (4) None of these

**114.** A particle is projected making angle 45° with horizontal having kinetic energy K. The kinetic energy at highest point will be-
(1) $K/\sqrt{2}$ (2) K/2 (3) 2K (4) K

**115.** Work done in time t on a body of mass m which is accelerated from rest to a speed v in time $t_1$ as a function of time t is given by

(1) $\frac{1}{2}m\frac{v}{t_1}t^2$ (2) $m\frac{v}{t_1}t^2$

(3) $\frac{1}{2}m\left(\frac{mv}{t_1}\right)^2 t^2$ (4) $\frac{1}{2}m\frac{v^2}{t_1^2}t^2$

**116.** A man is riding on a cycle with velocity 7.2 km/hr up a hill having a slope 1 in 20. The total mass of the man and cycle is 100 kg. The power of the man is-
(1) 98 W (2) 49 W (3) 196 W (4) 147 W

**117.** A truck of mass 10000 kg. moves up an inclined plane rising 1 in 50 with a speed of 36 km/h, then the power of engine- ($g = 10\ m/s^2$)
(1) 10 kW (2) 20 kW (3) 30 kW (4) 40 kW

**118.** If $\vec{F} = (60\hat{i} + 15\hat{j} - 3\hat{k})N$ and $\vec{V} = (2\hat{i} - 4\hat{j} + 5\hat{k})$ m/s then instantaneous power is-
(1) 195 watt (2) 45 watt
(3) 75 watt (4) 100 watt

**119.** A body is moved along a straight line by a machine delivering a constant power. The distance moved by the body in time 't' is proportional to-
(1) $t^{1/4}$ (2) $t^{1/2}$ (3) $t^{3/4}$ (4) $t^{3/2}$

**120.** A body of mass m kg initially at rest attains a velocity of v m/sec in time t under the action of a constant force F. The power supplied to the mass is-
(1) mv/t (2) $mv^2/t$ (3) Fv (4) Fv/2

**121.** A bullet of mass m is being fired from a stationary gun of mass M. If the velocity of the bullet is v, the velocity of the gun is-

(1) $\frac{Mv}{m+M}$ (2) $\frac{mv}{M}$

(3) $\frac{(M+m)v}{M}$ (4) $\frac{M+m}{Mv}$

**122.** A bomb at rest explodes in air in two equal fragments. If one of the fragments starts moving vertically upwards with velocity $v_0$, then the other fragment will move-
(1) Vertically up with velocity $v_0$
(2) Vertically downwards with velocity $v_0$
(3) In any arbitrary direction
(4) None of these

**123.** A body of mass M at rest explodes into three pieces, two of which of mass M/4 each, are thrown off in perpendicular directions with velocities of 3m/s and 4m/s respectively. The third piece will be thrown off with a velocity of-
(1) 1.5 m/s (2) 2.0 m/s
(3) 2.5 m/s (4) 3.0 m/s

**124.** Three particles with masses 10, 20 and 40gm are moving with velocities $10\hat{i}, 10\hat{j}$ and $10\hat{k}$ m/sec respectively. If due to some interaction the first particle comes to rest and the velocity of second becomes $(3\hat{i} + 4\hat{j})$ m/sec. then the velocity of third particle after the interaction is-
(1) $\hat{i} + \hat{j} + 5\hat{k}$ (2) $\hat{j} + 10\hat{k}$
(3) $\hat{i} + \hat{j} + 10\hat{k}$ (4) $\hat{i} + 3\hat{j} + 10\hat{k}$

**125.** A bullet is fired from the gun and the gun recoils. The kinetic energy of recoiled gun shall be-
(1) Equal to the kinetic energy of bullet
(2) No change
(3) More than the kinetic energy of bullet
(4) Less than the kinetic energy of bullet

**126.** When a $U^{238}$ nucleus originally at rest, decays by emitting an alpha particle having a speed 'u', the velocity of the residual nucleus is-

(1) $\frac{4u}{234}$ (2) $-\frac{4u}{238}$ (3) $\frac{4u}{238}$ (4) $-\frac{4u}{234}$

**127.** A ball is allowed to fall from a height of 8cm, if the ball is perfectly elastic, how much it rise after rebound-
(1) 8 cm (2) 1 cm (3) 0.5 cm (4) 0

**128.** A ball is allowed of fall from a height 1.0m. If the value of the coefficient of restitution is 0.6, then after the impact ball will go up to-
(1) 0.16 m (2) 0.36 m (3) 0.40 m (4) 0.60 m

**129.** A ball of mass m moving with velocity v collides elastically with another ball of identical mass coming from the opposite direction with velocity 2v. Their velocities after collisions are-
(1) – v, 2v (2) – 2v, v
(3) v, – 2v (4) 2v, – v

**130.** A scooter of 40 kg mass moving with velocity 4 m/s collides with another scooter of 60 kg mass and moving with velocity 2 m/s. After collision the two scooters stick to each other. The loss in kinetic energy-
(1) 392 J (2) 440 J (3) 48 J (4) 110 J

**131.** A ball is released from a height of 10 m. If after the impact there is loss of 40% in its energy, the ball shall rise upto-
(1) 6 m (2) 0.6 m (3) 10 m (4) 0.06 m

**132.** After falling from a height h and striking the ground twice, a ball rise up to the height [e = coefficient of restitution]
(1) he (2) $he^2$ (3) $he^3$ (4) $he^4$

**133.** A rubber ball is dropped from a height of 5m on a plane. On bouncing it rises to 1.8m. The ball loses its velocity on bouncing by a factor of-
(1) 16/25 (2) 2/5 (3) 3/5 (4) 9/25

**134.** If the coefficient of restitution be 0.5, what is the percentage loss of energy on each rebounding of a ball dropped from a height-
(1) 12.5 % (2) 25 % (3) 50 % (4) 75 %

**135.** A 1 kg ball moving at 12 m/sec. collides head on with 2 kg. ball moving in the opposite direction at 24 m/s. If the coefficient of restitution is 2/3 then how much energy is lost in collision-
(1) 240 Joule (2) 120 Joule
(3) 360 Joule (4) 400 Joule

**136.** Two identical balls each of mass 2 kg. are moving towards each other with the same speed of 5 m/s. They collide with each other, stick together and come to rest. What is the work done by the internal forces-
(1) 5 J (2) 10 J
(3) 25 J (4) 50 J

**137.** Two solid rubber balls, A and B having masses 200 and 400 g respectively are moving in opposite directions with velocity of A equal to 0.3 m/s. After collision the two balls come to rest, then the velocity of B is-
(1) 0.15 m/s. (2) 1.5 m/s.
(3) – 0.15 m/s. (4) None of the above

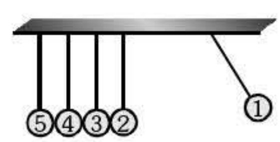
**138.** A ball of mass 'm' moving with a speed 'u' under goes a head-on elastic collision with a ball of mass (nm) initially at rest. The fraction of the incident energy transferred to the heaveir ball is-
(1) $\frac{n}{1+n}$ (2) $\frac{n}{(1+n)^2}$
(3) $\frac{2n}{(1+n)^2}$ (4) $\frac{4n}{(1+n)^2}$

**139.** A particle of mass $m_1$ collides head on with another stationary particle of $m_2$ perfectly inelastically ($m_2 > m_1$). The fraction of kinetic energy which is converted into heat in this collision is-
(1) $\frac{m_2}{m_1+m_2}$ (2) $\frac{m_1}{m_1+m_2}$
(3) $\frac{m_1}{m_1-m_2}$ (4) $\frac{m_2}{m_1-m_2}$

**140.** A ball after falling a distance of 5 metre from rest hits floor of a lift and rebounds. At the time of impact the lift was moving up with a velocity of 1m/sec. The velocity with which the ball rebounds just after impact is- (g = 10 m/sec²)
(1) 10 m/sec. (2) 11 m/sec.
(3) 12 m/sec. (4) 13 m/sec.

**141.** What is true in general when two particles collide
(1) the relative velocity of first particle w.r.t. second before and after collision remains the same
(2) the relative velocity of first particle w.r.t. second after collision is equal or less than opposite to the relative velocity before collision
(3) kinetic energy of particles after collision is equal to kinetic energy of particles after collision
(4) kinetic energy of particles after collision in inelastic collision is always greater than kinetic energy before collision

**142.** Five identical elastic balls are so suspended with strings of equal length in a row that the distances between adjacent balls are very small. If the extreme right ball is moved aside and released, then




(1) one extreme left hand ball will bounce off
(2) two extreme left hand balls will bounce off
(3) three extreme left hand balls will bounce off
(4) all the left hand four balls will bounce off

**143.** A ball collides elastically with another ball of the same mass. The collision is oblique and initially one of the ball was at rest. After the collision, the two balls move with same speeds. What will be the angle between the velocity of the balls after the collision?
(1) 30° (2) 45° (3) 60° (4) 90°

**144.** A chain of mass M is placed on a smooth table with 1/n of its length L hanging over the edge. The work done in pulling the hanging portion of the chain back to the surface of the table is

(1) MgL/n (2) MgL/2n

(3) $MgL/n^2$ (4) $MgL/2n^2$

**145.** A shell fired from a canon making an angle θ with horizontal explodes in two equal parts at the highest point of its path. One of the part retraces the path of the shell towards canon with the original speed v, then the velocity of the remaining part in m/s just after the explosion is

(1) $3v \cos \theta$ (2) $2v \cos \theta$

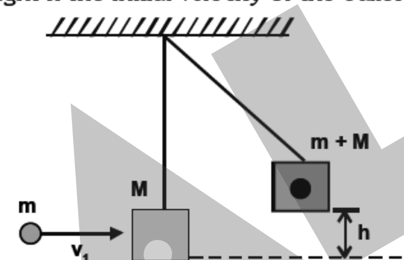
(3) $(3/2)v \cos \theta$ (4) $(\sqrt{3}/2)v\cos\theta$

**146.** A particle of mass 4m which is at rest explodes into three fragments. Two of the fragments, each of mass m are found to move with speed v each, in mutually perpendicular directions. The total energy released in the process of explosion is

(1) $3mv^2/2$ (2) $mv^2$

(3) $4mv^2$ (4) $2mv^2$

**147.** A bullet of mass m moving with a velocity $v_1$ strikes a suspended wooden block of mass M as shown in the figure and sticks to it. If the block rises to a height h the initial velocity of the bullet is




(1) $\frac{m+M}{m}\sqrt{2gh}$ (2) $\sqrt{2gh}$

(3) $\frac{M+m}{M}\sqrt{2gh}$ (4) $\frac{m}{M+m}\sqrt{2gh}$

**148.** A mass of 1 kg is thrown up with a velocity of 100 m/s. After 5 seconds, it explodes into two parts. One part of mass 400 gm comes down with a velocity 25 m/s. Calculate the velocity of other part

(1) 40 m/s↑ (2) 40 m/s ↓

(3) 100 m/s ↑ (4) 60 m/s ↑

**149.** A chain of mass M and length L is kept on a table with L/4 portion overhanging from edge. Work done by external force to put the hanging portion back on the table

(1) $\frac{MgL}{16}$ (2) $\frac{MgL}{32}$ (3) $\frac{MgL}{8}$ (4) $\frac{MgL}{12}$

**150.** A projectile of mass 3m explodes at highest point of its path. It breaks into three equal parts. One part retraces its path, the second one comes to rest. The distance of the third part from the point of projection when it finally lands on the ground is

(The range of the projectile was 100 m if no explosion would have taken place)

(1) 100 m (2) 150 m (3) 250 m (4) 300 m

**151.** A self propelled vehicle of mass m whose engine delivers constant power P has an acceleration $a = \frac{P}{mv}$ (Assume that there is no friction). In order to increase its velocity from $v_1$ to $v_2$, the distance it has to travel will be

(1) $\frac{3P}{m}(v_2^2 - v_1^2)$ (2) $\frac{m}{3P}(v_2^3 - v_1^3)$

(3) $\frac{m}{3P}(v_2^2 - v_1^2)$ (4) $\frac{m}{3P}(v_2 - v_1)$

**152.** Two masses m and 2m are attached to two ends of an ideal spring and the spring is in the compressed state. The energy of spring is 60 joule. If the spring is released, then

(1) the energy of both bodies will be same

(2) the energy of both bodies will be 10 J

(3) energy of smaller body will be 20 J

(4) energy of smaller body will be 40 J

**153.** When a 20 g mass hangs attached to one end of a light spring of length 10 cm, the spring stretches by 2 cm. The mass is pulled down until the total length of the spring is 14 cm. The elastic energy, (in Joule) stored in the spring is

(1) $4 \times 10^{-2}$ (2) $4 \times 10^{-3}$

(3) $8 \times 10^{-2}$ (4) $8 \times 10^{-3}$

**154.** A body of mass m moving with velocity v makes a head-on collision with another body of mass 2m which is initially at rest. The ratio of kinetic energies of colliding body before and after collision will be

(1) 9 : 1 (2) 1 : 1 (3) 4 : 1 (4) 2 : 1

**155.** A lead ball of mass 2 kg moving with a velocity of 1.5 $ms^{-1}$ hits against a ball of mass 3 kg at rest. If the second ball moves with a velocity of 1 $ms^{-1}$ after the impact in the original direction of motion of the first ball, the loss of K.E. due to impact is

(1) 0.033 J (2) 0.75 J

(3) 1.5 J (4) 2.25 J

**156.** A spring of force constant 800 N/m has an extension of 5 cm. The work done in extending it from 5 cm to 15 cm is

(1) 16 J (2) 8 J (3) 32 J (4) 24 J

**157.** A spring of spring constant $5 \times 10^3$ N/m is stretched initially by 5 cm from the unstretched position. Then the work required to stretch it further by another 5 cm is
(1) 12.50 N-m (2) 18.75 N-m
(3) 25.00 N-m (4) 6.25 N-m

**158.** Two spherical bodies of mass M and 5M and radii R and 2R respectively are released in free space with initial separation between their centres equal to 12 R. It they attract each other due to gravitational force only, then the distance covered by the smaller body just before collision is
(1) 2.5 R (2) 4.5 R (3) 7.5 R (4) 1.5 R

**159.** A bullet fired into a fixed target loses half of its velocity after penetrating 3cm. How much further it will penetrate before coming to rest, assuming that it faces constant resistance to motion ?
(1) 3.0 cm (2) 2.0 cm (3) 1.5 cm (4) 1.0 cm

**160.** A body A of mass M while falling vertically downwards under gravity breaks into two parts; a body B of mass $\frac{1}{3}$M and, a body C of mass $\frac{2}{3}$M. The centre of mass of bodies B and C taken together shifts compared to that of body A towards
(1) depends on height of breaking
(2) does not shift
(3) body C
(4) body B

**161.** A particle of mass 100 g is thrown vertically upwards with a speed of 5 m/s. The work done by the force of gravity during the time the particle goes up is
(1) – 0.5 J (2) –1.25 J
(3) 1.25 J (4) 0.5 J

**162.** An athlete in the Olympic games covers distance of 100 m in 10 s. His kinetic energy can be estimated to be in the range
(1) 200 J – 500 J
(2) $2 \times 10^5$ J – $3 \times 10^5$ J
(3) $2 \times 10^4$ J – $3 \times 10^4$ J
(4) $2 \times 10^3$ J – $3 \times 10^3$ J

**163.** A block of mass 0.50 kg is moving with a speed of 2.00 $ms^{-1}$ on a smooth surface. It strikes another mass of 1.00 kg and then they move together as a single body. The energy loss during the collision is :-
(1) 0.16 J (2) 1.00 J
(3) 0.67 J (4) 0.34 J

## CIRCULAR MOTION

**164.** A neutron star of enormous density is rotating at the rate of one rotation per second. If the radius of the star is 20 km, then the acceleration in $m/s^2$ units for any particle situated at the equator of the star will be :– ($\pi^2 \approx 10$)
(1) $8 \times 10^5$ (2) $20 \times 10^3$
(3) $12 \times 10^6$ (4) $4 \times 10^8$

**165.** A body of mass 1 kg tied to one end of string is revolved in a horizontal circle of radius 0.1 m with a speed of 3 revolution/sec, assuming the effect of gravity is negligible, then linear velocity, acceleration and tension in the string will be
(1) 1.88 m/s, 35.5 $m/s^2$, 35.5 N
(2) 2.88 m/s, 45.5 $m/s^2$, 45.5 N
(3) 3.88 m/s, 55.5 $m/s^2$, 55.5 N
(4) None of these

**166.** A particle move along a circular path of radius (r) with a uniform speed (v). The angle described by the particle in one second is given by
(1) $v\,r^{-1}$ (2) $v^{-1}\,r$ (3) $v\,r^{-2}$ (4) $v^2\,r$

**167.** A particle moves on a circular path of radius (r) with speed (v) if its speed and radius both are doubled then centripetal force is
(1) same (2) doubled
(3) quadrapuled (4) eight times

**168.** A mass of 2 kg is whirled in a horizontal circle by means of a string at an initial speed of 5 r.p.m. keeping the radius constant the tension in the string doubled the new speed is nearly
(1) 7 r.p.m. (2) 14 r.p.m.
(3) 10 r.p.m. (4) 20 r.p.m.

**169.** If the radius of circular path of two particles of same masses are in the ratio of 1 : 2 and have equal centripetal force their velocities should be in the ratio of
(1) $1 : \sqrt{2}$ (2) $\sqrt{2} : 1$ (3) 4 : 1 (4) 1 : 4

**170.** The radius of the circular path of a particle is doubled but its frequency of rotation kept constant. If the initial centripetal force be F, then the final value of centripetal force will be
(1) F (2) $\frac{F}{2}$ (3) 4F (4) 2F

**171.** A weightless thread can bear tension upto 3.7 kg wt. A stone of mass 500 gm is tied to it and revolved in a circular path of radius 4m in a vertical plane. If g = 10 $ms^{-2}$, then the maximum angular velocity of the stone will be
(1) 16 rad/s (2) $\sqrt{21}$ rad/s
(3) 2 rad/s (4) 4 rad/s

**172.** A body crosses the topmost point of a vertical circle with critical speed. What will be its centripetal acceleration when the string is horizontal
(1) g (2) 2g (3) 3g (4) 6g

**173.** A particle is moving along a circular path. The angular velocity, linear velocity, angular acceleration and certripetal acceleration of the particle at any instant respectively are $\vec{\omega}$, $\vec{v}$, $\vec{\alpha}$ are $\vec{a}_c$. Which of the following relation is/are correct
(a) $\vec{\omega} \perp \vec{v}$ (b) $\vec{\omega} \perp \vec{\alpha}$
(c) $\vec{v} \perp \vec{a}_c$ (d) $\vec{\omega} \perp \vec{a}_c$
(1) a,b,d (2) b,c,d (3) a,b,c (4) a,c,d

**174.** A body is revolving with a constant speed along a circle. If its direction of motion is reversed but the speed remains the same then :–

(a) the centripetal force will not suffer any change in magnitude

(b) the centripetal force will have its direction reversed

(c) the centripetal force will not suffer any change in direction

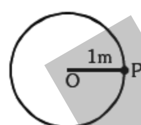
(d) the centripetal force is doubled

(1) a,b (2) b,c (3) c,d (4) a, c

**175.** A particle (P) is moving in a circle of radius (a) with a uniform speed (v). C is the centre of the circle and AB is a diametre. The angular velocity of particle when it is at point B about (A) and (C) are in the ratio :-

(1) 1 : 1 (2) 1 : 2 (3) 2 : 1 (4) 4 : 1

**176.** A mass tied to a string moves in a vertical circle with a uniform speed of 5 m/s as shown. At the point P the string breaks. The mass will reach a height above P of nearly




(1) 1 m

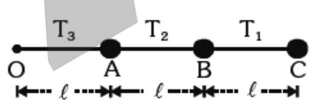
(2) 0.5 m

(3) 1.27 m (4) 1.25 m

**177.** A cyclist on the ground goes round a circular path of circumference 34.3 m in $\sqrt{22}$ second. The angle made by him, with the vertical, will be :–

(1) 45° (2) 40° (3) 42° (4) 48°

**178.** Three identical particles are joined together by a thread as shown in figure.




All the three particles are moving in circular path in a horizontal plane. If the velocity of the outermost particle is $v_0$, then the ratio of tensions in the three sections of the string is :–

(1) 3 : 5 : 7 (2) 3 : 4 : 5

(3) 7 : 11 : 6 (4) 3 : 5 : 6

**179.** The minimum velocity (in $ms^{-1}$) with which a car driver must traverse a flat curve of radius 150 m and coefficient of friction 0.6 to avoid skidding is-

(1) 60 (2) 30 (3) 15 (4) 25

**180.** The earth (mass = $6 \times 10^{24}$ kg) revolves around the sun with an angular velocity of $2 \times 10^{-7}$ radian/sec in a circular orbit of radius $1.5 \times 10^{8}$ km. The force exerted by the sun, on the earth is :-

(1) $6 \times 10^{19}$ N (2) $18 \times 10^{25}$ N

(3) $36 \times 10^{11}$ N (4) $27 \times 10^{39}$ N

**181.** A particle is acted upon by a force of constant magnitude which is always perpendicular to the velocity of the particle. The motion of the particle takes place in a plane, it follows that-

(1) Its velocity is constant
(2) Its acceleration is constant
(3) Its kinetic energy is constant
(4) It moves in a straight line

**182.** Which of the following statements is false for a particle moving in a circle with a constant angular speed ?

(1) The velocity vector is tangential to the circle
(2) The acceleration vector is tangential to the circle
(3) The acceleration vector points to the centre of the circle
(4) The velocity and acceleration vectors are perpendicular to each other

**183.** An annular ring with inner and outer radii $R_1$ and $R_2$ is rolling without slipping with a uniform angular speed. The ratio of the forces experienced by the two particles situated on the inner and outer parts of the ring $\frac{F_1}{F_2}$ is-

(1) $\frac{R_2}{R_1}$ (2) $\left(\frac{R_1}{R_2}\right)^2$

(3) 1 (4) $\frac{R_1}{R_2}$

## MISCELLANEOUS QUESTIONS

**184.** An example of an inertial reference frame is:

(1) any reference frame that is not accelerating

(2) a frame attached to a particle on which there are no forces

(3) any reference frame that is at rest

(4) a reference frame attached to the center of the universe

**185.** An object moving at constant velocity in an inertial frame must

(1) have a net force on it

(2) eventually stop due to gravity

(3) not have any force of gravity on it

(4) have zero net force on it

**186.** In SI units a force is numerically equal to the______, when the force is applied to it.
(1) velocity of the standard kilogram
(2) speed of the standard kilogram
(3) velocity of any object
(4) acceleration of the standard kilogram

**187.** Which of the following quantities is NOT a vector?
(1) Mass (2) Displacement
(3) Weight (4) Acceleration

**188.** A newton is the force
(1) of gravity on a 1 kg body
(2) of gravity on a 1 g body
(3) that gives a 1 g body an acceleration of 1 $cm/s^2$
(4) that gives a 1 kg body an acceleration of 1 $m/s^2$

**189.** The unit of force called the newton is
(1) 9.8 kg .$m/s^2$
(2) 1 kg .$m/s^2$
(3) derived by means of Newton's third law
(4) 1 kg of mass

**190.** A force of 1 N is
(1) 1 kg/s (2) 1 kg · m/s
(3) 1 kg · $m/s^2$ (4) 1 kg · $m^2/s$

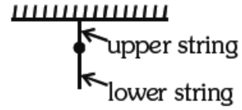
**191.** The standard 1-kg mass is attached to a compressed spring and the spring is released. If the mass initially has an acceleration of 5.6 $m/s^2$, the force of the spring has a magnitude of
(1) 2.8 N (2) 5.6 N (3) 11.2 N (4) 0

**192.** Acceleration is always in the direction
(1) of the displacement
(2) of the initial velocity
(3) of the final velocity
(4) of the net force

**193.** The term mass refers to the same physical concept as
(1) weight (2) inertia
(3) force (4) acceleration

**194.** The inertia of a body tends to cause the body to
(1) speed up
(2) slow down
(3) resist any change in its motion
(4) fall toward Earth

**195.** A heavy ball is suspended as shown. A quick jerk on the lower string will break that string but a slow pull on the lower string will break the upper string. The first result occurs because




(1) the force is too small to move the ball
(2) action and reaction is operating
(3) the ball has inertia
(4) air friction holds the ball back

**196.** When a certain force is applied to the standard kilogram its acceleration is 5.0 $m/s^2$. When the same force is applied to another object its acceleration is one-fifth as much. The mass of the object is
(1) 0.2 kg (2) 0.5 kg
(3) 1.0 kg (4) 5.0 kg

**197.** Mass differs from weight in that
(1) all objects have weight but some lack mass
(2) weight is a force and mass is not
(3) the mass of an object is always more than its weight
(4) mass can be expressed only in the metric system

**198.** The mass of a body
(1) is slightly different at different places on Earth
(2) is a vector
(3) is independent of the free-fall acceleration
(4) is the same for all bodies of the same volume

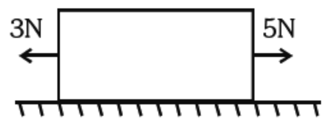
**199.** The mass and weight of a body
(1) different by a factor of 9.8
(2) are identical
(3) are the same physical quantities expressed in different units
(4) have the same ratio as that of any other body placed at that location

**200.** An object placed on an equal-arm balance requires 12 kg to balance it. When placed on a spring scale, the scale reads 12 kg. Everything (balance, scale, set of weights and object) is now transported to the Moon where the free-fall acceleration is one-sixth that on Earth. The new readings of the balance and spring scale (respectively) are
(1) 12 kg, 12 kg (2) 2 kg, 2 kg
(3) 12 kg, 2 kg (4) 2 kg, 12 kg

**201.** Two objects, one having three times the mass of the other, are dropped from the same height in a vacuum. At the end of their fall, their velocities are equal because
(1) anything falling in vacuum has constant velocity
(2) all objects reach the same terminal velocity
(3) the acceleration of the larger object is three times greater than that of the smaller object
(4) None of the above

**202.** A feather and a lead ball are dropped from rest in vacuum on the Moon. The acceleration of the feather is
(1) more than that of the lead ball
(2) the same as that of the lead ball
(3) less than that of the lead ball
(4) 9.8 $m/s^2$

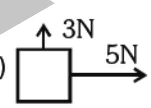
**203.** The block shown moves with constant velocity on a horizontal surface. Two of the forces on it are shown. A frictional force exerted by the surface is the only other horizontal force on the block. The frictional force is

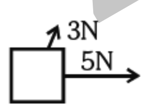


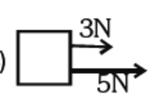

(1) 0
(2) 2 N, leftward
(3) 2 N, rightward
(4) slightly more than 2 N, leftward

**204.** Two forces, one with a magnitude of 3 N and the other with a magnitude of 5 N, are applied to an object. For which orientations of the forces shown in the diagrams is the magnitude of the acceleration of the object the least?

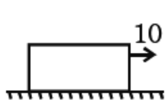
(1) 

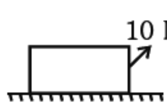
(2) 

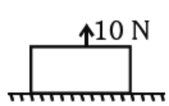
(3) 

(4) 


**205.** A crate rests on a horizontal surface and a woman pulls on it with a 10-N force. Rank the situations shown below according to the magnitude of the normal force exerted by the surface on the crate, least to greatest.



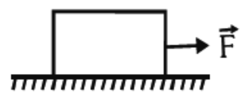
1


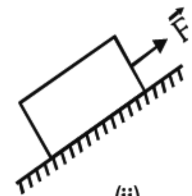
2


3

(1) 1, 2, 3 (2) 2, 1, 3
(3) 2, 3, 1 (4) 3, 2, 1

**206.** A heavy wooden block is dragged by a force F along a rough steel plate, as shown in the diagrams for two cases. The magnitude of the applied force F is the same for both cases. The normal force in (ii), as compared with the normal force in (i) is:



(i)


(ii)

(1) the same
(2) greater
(3) less
(4) less for some angles of the incline and greater for others

**207.** Equal forces $\vec{F}$ act on isolated bodies A and B. The mass of B is three times that of A. The magnitude of the acceleration of A is
(1) three times that of B
(2) 1/3 that of B
(3) the same as B
(4) nine times that of B

**208.** A car travels east at constant velocity. The net force on the car is
(1) east (2) west (3) up (4) 0

**209.** A constant force of 8.0 N is exerted for 4.0 s on a 16-kg object initially at rest. The change in speed of this object will be
(1) 0.5 m/s (2) 2 m/s
(3) 4 m/s (4) 8 m/s

**210.** A 6-kg object is moving south. A net force of 12N north on it results in the object having an acceleration of
(1) 2 $m/s^2$, north (2) 2 $m/s^2$, south
(3) 6 $m/s^2$, north (4) 18 $m/s^2$, north

**211.** A 9000-N automobile is pushed along a level road by four students who apply a total forward force of 500 N. Neglecting friction, the acceleration of the automobile is
(1) 0.055 $m/s^2$ (2) 0.54 $m/s^2$
(3) 1.8 $m/s^2$ (4) 9.8 $m/s^2$

**212.** An object rests on a horizontal frictionless surface. A horizontal force of magnitude F is applied. This force produces an acceleration
(1) only if F is larger than the weight of the object
(2) only while the object suddenly changes from rest to motion
(3) always
(4) only if the inertia of the object decreases

**213.** A 25-kg crate is pushed across a frictionless horizontal floor with a force of 20 N, directed 20° below the horizontal. The acceleration of the crate is
(1) 0.27 $m/s^2$ (2) 0.75 $m/s^2$
(3) 0.80 $m/s^2$ (4) 170 $m/s^2$

**214.** A ball with a weight of 1.5 N is thrown at an angle of 30° above the horizontal with an initial speed of 12 m/s. At its highest point, the net force on the ball is
(1) 9.8N, 30 below horizontal
(2) zero
(3) 9.8 N, up
(4) 1.5N, down

**215.** A brick slides on a horizontal surface. Which of the following will increase the magnitude of the frictional force on it?
(1) Putting a second brick on top
(2) Decreasing the surface area of contact
(3) Increasing the surface area of contact
(4) Decreasing the mass of the brick

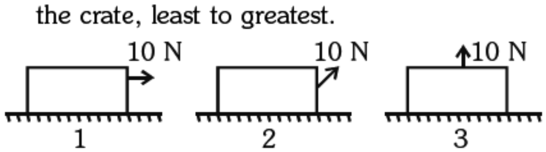
**216.** The coeffecient of kinetic friction
(1) is in the direction of the frictional force
(2) is in the direction of the normal force
(3) is the ratio of force to area
(4) is none of the above

**217.** When the brakes of an automobile are applied, the road exerts the greatest retarding force
(1) while the wheels are sliding
(2) just before the wheels start to slide
(3) when the automobile is going fastest
(4) when the acceleration is least

**218.** A forward horizontal force of 12 N is used to pull a 240-N crate at constant velocity across a horizontal floor. The coeffecient of friction is
(1) 0.5 (2) 0.05 (3) 2 (4) 0.2

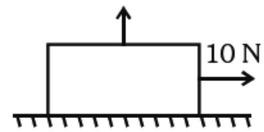
**219.** The speed of a 4.0-N hockey puck, sliding across a level ice surface, decreases at the rate of 0.61 $m/s^2$. The coeffecient of kinetic friction between the puck and ice is
(1) 0.062 (2) 0.41 (3) 9.8 (4) 1.2

**220.** A crate rests on a horizontal surface and a woman pulls on it with a 10-N force. No matter what the orientation of the force, the crate does not move. Rank the situations shown below according to the magnitude of the frictional force of the surface on the crate, least to greatest.




(1) 1, 2, 3 (2) 2, 1, 3
(3) 2, 3, 1 (4) 3, 2, 1

**221.** A crate with a weight of 50 N rests on a horizontal surface. A person pulls horizontally on it with a force of 10 N and it does not move. To start it moving, a second person pulls vertically upward on the crate. If the coeffecient of static friction is 0.4, what is the smallest vertical force for which the crate moves?




(1) 4 N (2) 10 N (3) 14 N (4) 25 N

**222.** A 40-N crate rests on a rough horizontal floor. A 12-N horizontal force is then applied to it. If the coeffecients of friction are $\mu_s = 0.5$ and $\mu_k = 0.4$, the magnitude of the frictional force on the crate is
(1) 8 N (2) 12 N (3) 16 N (4) 20 N

**223.** A 24-N horizontal force is applied to a 40-N block initially at rest on a rough horizontal surface. If the coeffecients of friction are $\mu_s = 0.5$ and $\mu_k = 0.4$, the magnitude of the frictional force on the block is
(1) 8 N (2) 12 N
(3) 16 N (4) 20 N

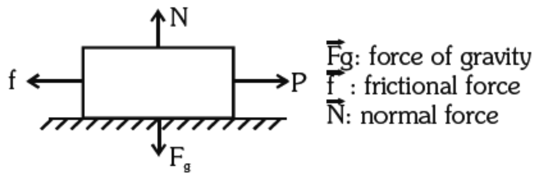
**224.** A horizontal shove of at least 200 N is required to start moving a 800-N crate initially at rest on a horizontal floor. The coefficient of static friction is
(1) 0.25 (2) 0.125
(3) 0.50 (4) 4.00

**225.** A force $\vec{F}$ (larger than the largest possible force of static friction) is applied to the left to an object moving to the right on a horizontal surface. Then
(1) the object must be moving at constant speed
(2) $\vec{F}$ and the friction force act in opposite directions
(3) the object must be slowing down
(4) the object must be speeding up

**226.** A bureau rests on a rough horizontal surface ($\mu_s = 0.50$, $\mu_k = 0.40$). A constant horizontal force, just sufficient to start the bureau in motion, is then applied. The acceleration of the bureau is
(1) 0 (2) 0.98 $m/s^2$
(3) 3.3 $m/s^2$ (4) 4.5 $m/s^2$

**227.** A car is traveling at 15 m/s on a horizontal road. The brakes are applied and the car skids to a stop in 4.0 s. The coeffecient of kinetic friction between the tires and road is
(1) 0.38 (2) 0.69
(3) 0.76 (4) 0.92

**228.** A boy pulls a wooden box along a rough horizontal floor at constant speed by means of a force $\vec{P}$ as shown. In the diagram f is the magnitude of the force of friction, N is the magnitude of the normal force, and $F_g$ is the magnitude of the force of gravity. Which of the following must be true?



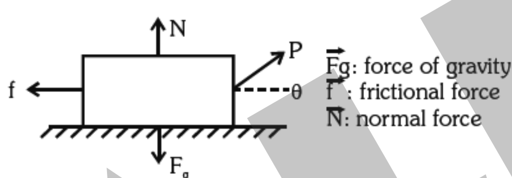

(1) $P = f$ and $N = F_g$

(2) $P = f$ and $N > F_g$

(3) $P > f$ and $N < F_g$

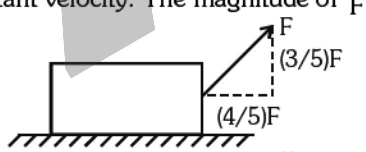
(4) $P > f$ and $N = F_g$

**229.** A boy pulls a wooden box along a rough horizontal floor at constant speed by means of a force $\vec{P}$ as shown. In the diagram f is the magnitude of the force of friction, N is the magnitude of the normal force, and $F_g$ is the magnitude of the force of gravity. Which of the following must be true?



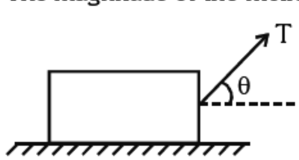

(1) $P = f$ and $N = Fg$ (2) $P = f$ and $N > Fg$
(3) $P > f$ and $N < Fg$ (4) $P > f$ and $N = Fg$

**230.** A 400-N block is dragged along a horizontal surface by an applied force F as shown. The coefficient of kinetic friction is $\mu_k = 0.4$ and the block moves at constant velocity. The magnitude of $\vec{F}$ is



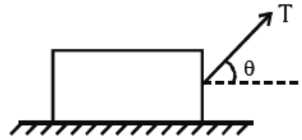

(1) 100 N (2) 153.84 N
(3) 200 N (4) 290 N

**231.** A block of mass m is pulled at constant velocity along a rough horizontal floor by an applied force $\vec{T}$ as shown. The magnitude of the frictional force is




(1) T cosθ (2) T sinθ (3) zero (4) mgcosθ

**232.** A block of mass m is pulled along a rough horizontal floor by an applied force $\vec{T}$ as shown. The vertical component of the force exerted on the block by the floor is




(1) mg (2) mg – T cosθ
(3) mg + T cosθ (4) mg –T sinθ

**233.** A 12-kg crate rests on a horizontal surface and a boy pulls on it with a force that is 30 below the horizontal. If the coeffecient of static friction is 0.40, the minimum magnitude force he needs to start the crate moving is
(1) 44 N (2) 47 N (3) 54 N (4) 71 N

**234.** A crate resting on a rough horizontal floor is to be moved horizontally. The coeffecient of static friction is 0.40. To start the crate moving with the weakest possible applied force, in what direction should the force be applied?
(1) Horizontal
(2) 24° below the horizontal
(3) 22° above the horizontal
(4) 24° above the horizontal

**235.** A 50-N force is applied to a crate on a horizontal rough floor, causing it to move horizontally. If the coeffecient of kinetic friction is 0.50, in what direction should the force be applied to obtain the greatest acceleration?
(1) Horizontal
(2) 60° above the horizontal
(3) 30° above the horizontal
(4) 27° above the horizontal

**236.** A professor holds an eraser against a vertical chalkboard by pushing horizontally on it. He pushes with a force that is much greater than is required to hold the eraser. The force of friction exerted by the board on the eraser increases if he
(1) pushes with slightly greater force
(2) pushes with slightly less force
(3) stops pushing
(4) pushes so his force is slightly downward but has the same magnitude

**237.** A horizontal force of 12 N pushes a 0.5-kg book against a vertical wall. The book is initially at rest. If the coeffecients of friction are $\mu_k = 0.6$ and $\mu_s = 0.8$ which of the following is true?
(1) The magnitude of the frictional force is 4.9 N
(2) The magnitude of the frictional force is 7.2 N
(3) The normal force is 4.9 N
(4) The book will start moving and accelerate

**238.** A horizontal force of 5.0 N pushes a 0.50-kg book against a vertical wall. The book is initially at rest. If the coeffecients of friction are $\mu_s = 0.6$ and $\mu k = 0.80$, the magnitude of the frictional force is:

(1) 0 (2) 4.9 N
(3) 3.0 N (4) 4.0 N

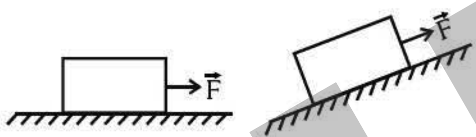
**239.** A horizontal force of 12 N pushes a 0.50-kg book against a vertical wall. The book is initially at rest. If $\mu_s = 0.6$ and $\mu_k = 0.80$, the acceleration of the book in $m/s^2$ is

(1) 0 (2) 9.4 $m/s^2$
(3) 9.8 $m/s^2$ (4) 14.4 $m/s^2$

**240.** A horizontal force of 5.0 N pushes a 0.50-kg block against a vertical wall. The block is initially at rest. If $\mu_s = 0.60$ and $\mu_k = 0.80$, the acceleration of the block in $m/s^2$ is

(1) 0 (2) 1.8
(3) 6.0 (4) 8.0

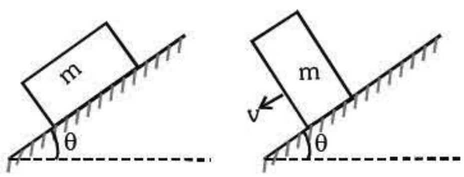
**241.** A heavy wooden block is dragged by a force F along a rough steel plate, as shown below for two possible situations. The magnitude of F is the same for the two situations. The magnitude of the frictional force in (ii), as compared with that in (i) is




(i) (ii)

(1) the same
(2) greater
(3) less
(4) less for some angles and greater for others

**242.** A block is first placed on its long side and then on its short side on the same inclined plane, as shown. The block slides down the plane on its short side but remains at rest on its long side. A possible explanation is:




(i) (ii)

(1) the short side is smoother
(2) the frictional force is less because the contact area is less
(3) the center of gravity is higher in the second case
(4) the normal force is less in the second case

**243.** A box rests on a rough board 10 meters long. When one end of the board is slowly raised to a height of 6 meters above the other end, the box begins to slide. The coeffecient of static friction is:

(1) 0.8 (2) 0.25 (3) 0.4 (4) 0.75

**244.** A block is placed on a rough wooden plane. It is found that when the plane is tilted 30 to the horizontal, the block will slide down at constant speed. The coe cient of kinetic friction of the block with the plane is

(1) 0.500 (2) 0.577
(3) 1.73 (4) 0.866

**245.** A crate is sliding down an incline that is 35° above the horizontal. If the coeffecient of kinetic friction is 0.40, the acceleration of the crate is

(1) 0 (2) 2.4 $m/s^2$
(3) 5.8 $m/s^2$ (4) 8.8 $m/s^2$

**246.** A 5.0-kg crate is resting on a horizontal plank. The coeffecient of static friction is 0.50 and the coeffecient of kinetic friction is 0.40. After one end of the plank is raised so the plank makes an angle of 25° with the horizontal, the force of friction is

(1) 0 (2) 18N (3) 21N (4) 22N

**247.** A 5.0-kg crate is resting on a horizontal plank. The coeffecient of static friction is 0.50 and the coeffecient of kinetic friction is 0.40. After one end of the plank is raised so the plank makes an angle of 30° with the horizontal, the force of friction is

(1) 0 (2) 18N
(3) 21N (4) 22N

**248.** A 5.0-kg crate is on an incline that makes an angle of 30° with the horizontal. If the coeffecient of static friction is 0.50, the minimum force that can be applied parallel to the plane to hold the crate at rest is

(1) 0 (2) 3.3 N (3) 30 N (4) 46 N

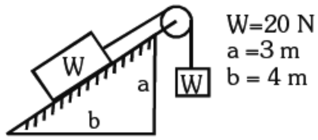
**249.** A 5.0-kg crate is on an incline that makes an angle of 30° with the horizontal. If the coeffecient of static friction is 0.5, the maximum force that can be applied parallel to the plane without moving the crate is

(1) 0 (2) 3.3 N (3) 30 N (4) 46 N

**250.** Block A, with mass $m_A$, is initially at rest on a horizontal soor. Block B, with mass $m_B$, is initially at rest on the horizontal top surface of A. The coeffecient of static friction between the two blocks is $\mu_s$. Block A is pulled with a horizontal force. It begins to slide out from under B if the force is greater than

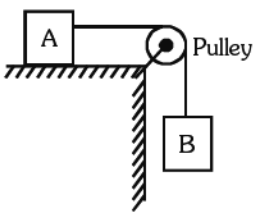
(1) $m_Ag$ (2) $m_Bg$
(3) $\mu_s m_Ag$ (4) $\mu_s(m_A + m_B)g$

**251.** The system shown remains at rest. Each block weighs 20 N. The force of friction on the upper block is



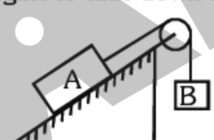

(1) 4 N (2) 8 N
(3) 12 N (4) 16 N

**252.** Block A, with a mass of 50 kg, rests on a horizontal table top. The coeffecient of static friction is 0.40. A horizontal string is attached to A and passes over a massless, frictionless pulley as shown. The smallest mass $m_B$ of block B, attached to the dangling end, that will start A moving when it is attached to the other end of the string is



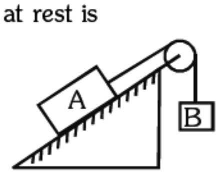

(1) 20kg (2) 30 kg
(3) 40 kg (4) 50 kg

**253.** Block A, with a mass of 10 kg, rests on a 35° incline. The coeffecient of static friction is 0.40. An attached string is parallel to the incline and passes over a massless, frictionless pulley at the top. The largest mass $m_B$ of block B, attached to the dangling end, for which A begins to slide down the incline is



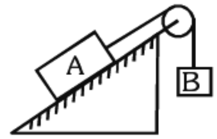

(1) 2.5 kg (2) 3.5 kg
(3) 5.9 kg (4) 9.0 kg

**254.** Block A, with a mass of 10 kg, rests on a 35 incline. The coeffecient of static friction is 0.40. An attached string is parallel to the incline and passes over a massless, frictionless pulley at the top. The largest mass $m_B$, attached to the dangling end, for which A remains at rest is



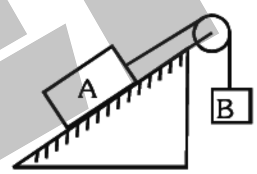

(1) 2.5 kg (2) 3.5 kg
(3) 5.9 kg (4) 9.0 kg

**255.** Block A, with a mass of 10 kg, rests on a 30° incline. The coeffecient of kinetic friction is 0.20. The attached string is parallel to the incline and passes over a massless, frictionless pulley at the top. Block B, with a mass of 8.0 kg, is attached to the dangling end of the string. The acceleration of B is




(1) 0.69 $m/s^2$, up the plane
(2) 0.69 $m/s^2$, down the plane
(3) 2.6 $m/s^2$, up the plane
(4) 2.6 $m/s^2$, down the plane

**256.** Block A, with a mass of 10 kg, rests on a 30° incline. The coeffecient of kinetic friction is 0.20. The attached string is parallel to the incline and passes over a massless, frictionless pulley at the top. Block B, with a mass of 3.0 kg, is attached to the dangling end of the string. The acceleration of B is




(1) 0.20 $m/s^2$, up (2) 0.20 $m/s^2$, down
(3) 2.8 $m/s^2$, up (4) 2.8 $m/s^2$, down

**257.** A 1000-kg airplane moves in straight flight at constant speed. The force of air friction is 1800 N. The net force on the plane is

(1) zero (2) 11800 N
(3) 1800 N (4) 9800 N

**258.** Why do raindrops fall with constant speed during the later stages of their descent?

(1) The gravitational force is the same for all drops
(2) Air resistance just balances the force of gravity
(3) The drops all fall from the same height
(4) The force of gravity is negligible for objects as small as raindrops

**259.** A ball is thrown downward from the edge of a cliff with an initial speed that is three times the terminal speed. Initially its acceleration is

(1) upward and greater than g
(2) upward and less than g
(3) downward and greater than g
(4) downward and less than g

**260.** A ball is thrown upward into the air with a speed that is greater than terminal speed. On the way up it slows down and, after its speed equals the terminal speed but before it gets to the top of its trajectory:
(1) its speed is constant
(2) it continues to slow down
(3) it speeds up
(4) its motion becomes jerky

**261.** A ball is thrown upward into the air with a speed that is greater than terminal speed. It lands at the place where it was thrown. During its flight the force of air resistance is the greatest
(1) just after it is thrown
(2) halfway up
(3) at the top of its trajectory
(4) halfway down

**262.** Uniform circular motion is the direct consequence of
(1) Newton.s third law
(2) a force that is always tangent to the path
(3) an acceleration tangent to the path
(4) a force of constant magnitude that is always directed toward the same fixed point

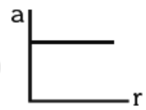
**263.** An object moving in a circle at constant speed
(1) must have only one force acting on it
(2) is not accelerating
(3) is held to its path by centrifugal force
(4) has an acceleration of constant magnitude

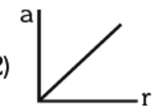
**264.** An object of mass m and another object of mass 2 m are each forced to move along a circle of radius 1.0 m at a constant speed of 1.0 m/s. The magnitudes of their accelerations are
(1) equal
(2) in the ratio of $\sqrt{2}$ : 1
(3) in the ratio of 2 : 1
(4) in the ratio of 4 : 1

**265.** The magnitude of the force required to cause a 0.04-kg object to move at 0.6 m/s in a circle of radius 1.0m is
(1) $2.4 \times 10^{-2}$ N (2) $1.4 \times 10^{-2}$ N
(3) $1.4\pi \times 10^{-2}$ N (4) $2.4\pi^2 \times 10^{-2}$ N

**266.** A 0.2-kg stone is attached to a string and swung in a circle of radius 0.6 m on a horizontal and frictionless surface. If the stone makes 150 revolutions per minute, the tension force of the string on the stone is
(1) 0.03 N (2) 0.2 N
(3) 0.9 N (4) 30 N

**267.** Which of the following five graphs is correct for a particle moving in a circle of radius r at a constant speed of 10 m/s?

(1)



(2)



(3)



(4)



**268.** An object moves around a circle. If the radius is doubled keeping the speed the same then the magnitude of the centripetal force must be
(1) twice as great (2) half as great
(3) four times as great (4) one-fourth as great

**269.** An object moves in a circle. If the mass is tripled, the speed halved, and the radius unchanged, then the magnitude of the centripetal force must be multiplied by a factor of
(1) 3/2 (2) 3/4
(3) 9/4 (4) 6

**270.** If a satellite moves above Earth's atmosphere in a circular orbit with constant speed, then
(1) its acceleration and velocity are always in the same direction
(2) the net force on it is zero
(3) its velocity is constant
(4) its acceleration is toward the Earth

**271.** A 800-N passenger in a car presses against the car door with a 200 N force when the car makes a left turn at 13 m/s. The (faulty) door will pop open under a force of 800 N. Of the following, the least speed for which the passenger is thrown out of the car is
(1) 14 m/s (2) 19 m/s
(3) 20 m/s (4) 26 m/s

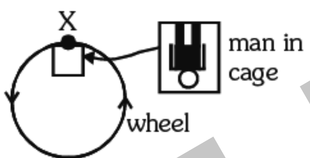
**272.** If a certain car, going with speed $v_1$, rounds a level curve with a radius $R_1$, it is just on the verge of skidding. If its speed is now doubled, the radius of the tightest curve on the same road that it can round without skidding is
(1) $2R_1$ (2) $4R_1$
(3) $R_1/2$ (4) $R_1/4$

**273.** An automobile moves on a level horizontal road in a circle of radius 30 m. The coeffecient of friction between tyres and road is 0.50. The maximum speed with which this car can round this curve is
(1) 3.0m/s (2) 4.9m/s
(3) 9.8m/s (4) 12m/s

**274.** The driver of a 1000-kg car tries to turn through a circle of radius 100 m on an unbanked curve at a speed of 10 m/s. The actual frictional force between the tyres and slippery road has a magnitude of 900 N. The car
(1) slides into the inside of the curve
(2) makes the turn
(3) slows down due to the frictional force
(4) slides off to the outside of the curve

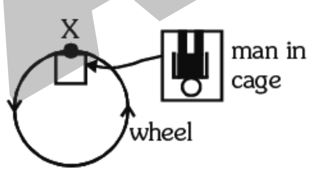
**275.** A car rounds a 75-m radius curve at a constant speed of 18 m/s. A ball is suspended by a string from the ceiling the car and moves with the car. The angle between the string and the vertical is
(1) 0° (2) 1.4° (3) 24° (4) 90°

**276.** A giant wheel, having a diameter of 40 m, is fitted with a cage and platform on which a man of mass m stands. The wheel is rotated in a vertical plane at such a speed that the force exerted by the man on the platform is equal to his weight when the cage is at X, as shown. The net force on the man at point X is




(1) zero (2) mg, down
(3) mg, up (4) 2mg, down

**277.** A giant wheel, 40 m in diameter, is fitted with a cage and platform on which a man can stand. The wheel rotates at such a speed that when the cage is at X (as shown) the force exerted by the man on the platform is equal to his weight. The speed of the man is




(1) 14m/s (2) 20m/s (3) 28m/s (4) 80m/s

**278.** A person riding a Ferris wheel is strapped into her seat by a seat belt. The wheel is spun so that the centripetal acceleration is g. Select the correct combination of forces that act on her when she is at the top. In the table $F_g$ = force of gravity, down; $F_b$ = seat belt force, down; and $F_s$ = seat force, up.

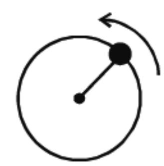
| | Fg | Fb | Fs |
|---|---|---|---|
| (1) | 0 | mg | 0 |
| (2) | mg | 0 | 0 |
| (3) | 0 | 0 | mg |
| (4) | mg | mg | 0 |

**279.** One end of a 1.0-m long string is fixed, the other end is attached to a 2.0-kg stone. The stone swings in a vertical circle, passing the bottom point at 4.0 m/s. The tension force of the string at this point is about
(1) 0 (2) 12 N (3) 20 N (4) 52 N

**280.** One end of a 1.0-m string is fixed, the other end is attached to a 2.0-kg stone. The stone swings in a vertical circle, passing the top point at 4.0 m/s. The tension force of the string (in newtons) at this point is about
(1) 0 (2) 12 (3) 20 (4) 32

**281.** A coin is placed on a horizontal phonograph turntable. Let N be the magnitude of the normal force exerted by the turntable on the coin, f be the magnitude of the frictional force exerted by the turntable on the coin, and fs, max be the maximum possible force of static friction. The speed of the turntable is increased in small steps. If the coin does not slide, then
(1) N increases, f increases, and fs, max stays the same
(2) N increases, f increases, and fs, max increases
(3) f increases and both N and fs, max stay the same
(4) N, f, and fs, max all stay the same

**282.** The iron ball shown is being swung in a vertical circle at the end of a 0.7-m long string. How slowly can the ball go through its top position without having the string go slack?



(1) 1.3 m/s (2) 2.6 m/s
(3) 3.9 m/s (4) 6.9 m/s

**283.** A block is suspended by a rope from the ceiling of a car. When the car rounds a 45-m radius horizontal curve at 22 m/s (about 50 mph), what angle does the rope make with the vertical?
(1) 0° (2) 25° (3) 48° (4) 65°

**284.** Circular freeway entrance and exit ramps are commonly banked to handle a car moving at 13 m/s. To design a similar ramp for 26 m/s one should
(1) increase radius by factor of 2
(2) decrease radius by factor of 2
(3) increase radius by factor of 4
(4) decrease radius by factor of 4



node05\B0AI-B0\CBSE\Excellent module\9th\Physics-1\Unit-2\2.IJSO-UNIT-2_(Ex).p65

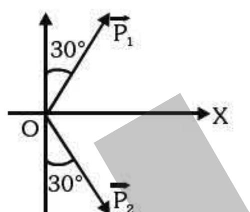
**285.** At what angle should the roadway on a curve with a 50 m radius be banked to allow cars to negotiate the curve at 12 m/s even if the roadway is icy (and the frictional force is zero)?
(1) 0° (2) 16° (3) 18° (4) 35°

**QUESTIONS ASKED IN PREVIOUS EXAMS**

**286.** A certain force acting on a body of mass 2 kg increases its velocity from 6 m/s to 15 m/s in 2 s. The work done by the force during this interval is
(1) 27 J (2) 3 J (3) 94.5 J (4) 189 J

**287.** Which one of the following statements is INCORRECT ?
(1) If the net force on a body is zero, its velocity is constant or zero.
(2) If the net force on a body is zero, its acceleration is constant and nonzero.
(3) If the velocity of a body is constant, its acceleration is zero.
(4) A body may have a varying velocity yet a constant speed.

**288.** Two forces each of magnitude P act on a body placed at a point O as shown. The force necessary to keep the body at rest is of magnitude.



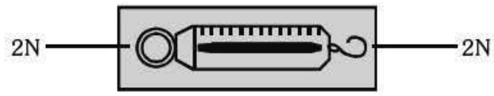

(1) P along + X axis (2) P along – X axis
(3) 2P along + X axis (4) P/2 along – X axis

**289.** A certain force applied to a body A gives it an acceleration of 10 $ms^{-2}$. The same force applied to body B gives it an acceleration of 15 $ms^{-2}$. If the two bodies are joined together and the same force is applied to the cobination, the acceleration will be
(1) 6 $ms^{-2}$ (2) 25 $ms^{-2}$
(3) 12.5 $ms^{-2}$ (4) 9 $ms^{-2}$

**290.** Which of the following does NOT involve friction ?
(1) Writing on a paper using a pencil.
(2) Turning a car to the left on a horizontal road.
(3) A car at rest parked on an inclined road.
(4) Motion of a satellite around the earth.

**291.** A particle of mass 0.5 kg travelling with a velocity of 2 $ms^{-1}$ experiences acceleration of 2 $ms^{-2}$ for 9 s. The workdone by the force on the particle during this period is
(1) 99 J (2) 101 J (3) 190 J (4) 396 J

**292.** What is the reading of the spring balance shown in the figure below ?




(1) 0 (2) 2 N (3) 4 N (4) 6N

**293.** When a car turns on a curved road, you are pushed against one of the doors of the car because of
(1) inertia
(2) the centripetal force
(3) the centrifugal force
(4) the frictional force

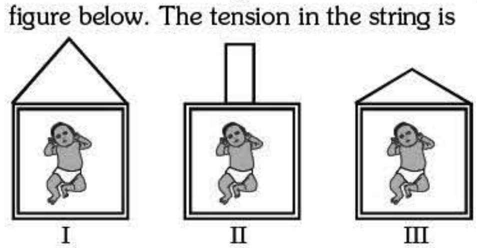
**294.** An object of mass 1 kg is made to slide down a smooth inclined plane of length 20 m. If the kinetic energy possessed by the body at the bottom of the plane is 100 J, then the inclination of the plane with the hoizontal is (take g =10$ms^{-2}$)
(1) 45° (2) 37° (3) 60° (4)30°

**295.** A block of mass 2 kg placed on a floor experiences an external force in horizontal direction of 20 N, frictional force of 6 N. The body travels a distance of 10 m under the combined effect of all these force. If initially body is at rest then what is the kinetic energy of the body at the end of 10 m
(1) 140 J (2) 260 J (3) 60 J (4) 460 J

**296.** The "reaction" force does not cancel the "action" force because
(1) the action force is greater than the reaction force.
(2) the reaction force exists only after the action force is removed.
(3) the reaction force is greater than the action force
(4) they act on different bodies.

**297.** A body is in equilibrium under the combined action of several forces then.
(1) all the forces must be applied at the same point.
(2) all the forces form pairs of equal and opposite forces.
(3) the sum of the torques about any point must always be equal to zero.
(4) the lines of action of all the forces must pass through the centre of gravity of the body.

**298.** A photo frame can be hung on the wall with string in three different ways as shown in the adjacent figure below. The tension in the string is




(1) least in I (2) greatest in II
(3) greatest in III (4) least in III

**299.** If a force acting is conservating only when

(1) work done by this force is zero when the particle moves once around any closed path

(2) it obeys Newton's third law

(3) its work is the change in the K.E. of the particle

(4) it is not a frictional force

**300.** A lift is moving up at constant speed. Consider the following statements :

I. The tension in the string is constant

II. The K.E. of the elevator is constant

III. The gravitational P.E. of the earth lift system is constant.

IV. The acceleration of the elevator is zero.

V. The mechanical energy of the earth-lift system is constant.

Choose the correct option

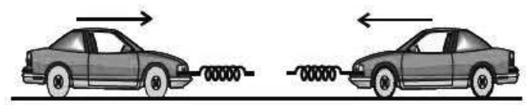
(1) Only II and V are true

(2) Only IV and V are true

(3) Only I, II and III are true

(4) Only I, II and IV are true

**301.** Two toy cars (a and b) fixed with spring at front, collide as shown in the figure below. 'a' has a mass of 200 g and is initially moving to the right. Car 'b' has a mass of 300 g and is initially at rest. When the separation between the cars is minimum,




(1) car b is at rest

(2) car a has come to rest

(3) both cars have the same kinetic energy (K.E.)

(4) the K.E. of the system is at a minimum

## ANSWER KEY

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Que. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 |
| Ans. | 2 | 3 | 1 | 1 | 4 | 3 | 1 | 2 | 2 | 1 | 2 | 4 | 2 | 2 | 3 | 1 | 1 | 3 | 1 | 1 |
| Que. | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 |
| Ans. | 4 | 2 | 2 | 2 | 3 | 4 | 2 | 1 | 4 | 1 | 1 | 2 | 3 | 3 | 2 | 4 | 4 | 3 | 4 | 2 |
| Que. | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 |
| Ans. | 2 | 2 | 4 | 1 | 3 | 3 | 2 | 2 | 1 | 2 | 2 | 2 | 1 | 2 | 3 | 2 | 4 | 1 | 3 | 1 |
| Que. | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 |
| Ans. | 1 | 2 | 1 | 3 | 3 | 1 | 3 | 4 | 2 | 2 | 2 | 2 | 4 | 1 | 4 | 4 | 4 | 1 | 3 | 1 |
| Que. | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
| Ans. | 1 | 2 | 2 | 2 | 4 | 4 | 1 | 3 | 3 | 3 | 1 | 1 | 2 | 2 | 4 | 3 | 1 | 3 | 2 | 2 |
| Que. | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 |
| Ans. | 4 | 1 | 1 | 2 | 3 | 4 | 3 | 1 | 1 | 3 | 3 | 4 | 1 | 2 | 4 | 1 | 2 | 2 | 4 | 4 |
| Que. | 121 | 122 | 123 | 124 | 125 | 126 | 127 | 128 | 129 | 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 |
| Ans. | 2 | 2 | 3 | 4 | 4 | 4 | 1 | 2 | 2 | 3 | 1 | 4 | 3 | 4 | 1 | 4 | 3 | 4 | 1 | 3 |
| Que. | 141 | 142 | 143 | 144 | 145 | 146 | 147 | 148 | 149 | 150 | 151 | 152 | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 160 |
| Ans. | 2 | 1 | 4 | 4 | 1 | 1 | 1 | 3 | 2 | 3 | 2 | 4 | 4 | 1 | 2 | 2 | 2 | 3 | 4 | 2 |
| Que. | 161 | 162 | 163 | 164 | 165 | 166 | 167 | 168 | 169 | 170 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 | 180 |
| Ans. | 2 | 4 | 3 | 1 | 1 | 1 | 2 | 1 | 1 | 4 | 4 | 3 | 4 | 4 | 2 | 3 | 1 | 4 | 2 | 3 |
| Que. | 181 | 182 | 183 | 184 | 185 | 186 | 187 | 188 | 189 | 190 | 191 | 192 | 193 | 194 | 195 | 196 | 197 | 198 | 199 | 200 |
| Ans. | 3 | 2 | 4 | 1 | 4 | 4 | 1 | 4 | 2 | 3 | 2 | 4 | 2 | 3 | 3 | 4 | 2 | 3 | 4 | 3 |
| Que. | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 | 211 | 212 | 213 | 214 | 215 | 216 | 217 | 218 | 219 | 220 |
| Ans. | 4 | 2 | 2 | 1 | 4 | 3 | 1 | 4 | 2 | 1 | 2 | 3 | 2 | 4 | 1 | 4 | 2 | 2 | 1 | 4 |
| Que. | 221 | 222 | 223 | 224 | 225 | 226 | 227 | 228 | 229 | 230 | 231 | 232 | 233 | 234 | 235 | 236 | 237 | 238 | 239 | 240 |
| Ans. | 4 | 2 | 3 | 1 | 3 | 2 | 1 | 1 | 3 | 2 | 1 | 4 | 4 | 3 | 4 | 4 | 1 | 4 | 1 | 2 |
| Que. | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 |
| Ans. | 3 | 1 | 4 | 2 | 2 | 3 | 2 | 2 | 4 | 4 | 2 | 1 | 1 | 4 | 1 | 1 | 1 | 2 | 1 | 2 |
| Que. | 261 | 262 | 263 | 264 | 265 | 266 | 267 | 268 | 269 | 270 | 271 | 272 | 273 | 274 | 275 | 276 | 277 | 278 | 279 | 280 |
| Ans. | 1 | 4 | 4 | 1 | 2 | 4 | 4 | 2 | 2 | 4 | 4 | 2 | 4 | 4 | 3 | 4 | 2 | 2 | 4 | 2 |
| Que. | 281 | 282 | 283 | 284 | 285 | 286 | 287 | 288 | 289 | 290 | 291 | 292 | 293 | 294 | 295 | 296 | 297 | 298 | 299 | 300 |
| Ans. | 3 | 2 | 3 | 3 | 2 | 4 | 2 | 2 | 1 | 4 | 1 | 2 | 1 | 4 | 1 | 4 | 3 | 3 | 1 | 4 |
| Que. | 301 | | | | | | | | | | | | | | | | | | | |
| Ans. | 4 | | | | | | | | | | | | | | | | | | | |